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SUBJECT: Color Reproduction Systems Review

TASK/PROBLEM

1. In view of the recent importance attached to color photography by the intelligence community, investigate and determine the most suitable means to reproduce and utilize multiple copies of color materials. Determine the most suitable reproduction system and types of equipment to be used in all phases of the reproduction cycle. Also, attempt to define how color photography can best be utilized by the photo interpreter.

INTRODUCTION

2. Acquisition Information: Reference to the acquisition phase throughout the report is a necessary consideration in the selection of materials for subsequent reproduction systems. Acquisition altitudes are especially significant, and are therefore defined as follows:

a. Low altitude - less than 5,000 feet.
b. Medium altitude - 5,000 feet to 50,000 feet.
c. High altitude - over 50,000 feet (non-orbital).
d. Very high altitude - orbital condition.

3. General Background Information

a. High quality faithful color reproductions of ground scenes involve consideration of the acquisition stage. The natural phenomena of haze and altitude are basic factors in selecting the acquisition film. Natural sunlight penetrating the atmosphere and being reflected back to the camera altitude is scattered so that unequal quantities of red, green, and blue light energy reach the camera film plane. At high and very high altitudes this effect is most pronounced. Thus, the processed color acquisition film image may appear unnatural to the observer. Further, as acquisition altitude increases, the scene brightness range is reduced. The combination of low scene brightness and distorted color hues of known objects in the color original will appear

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HAZE ATTENUATION

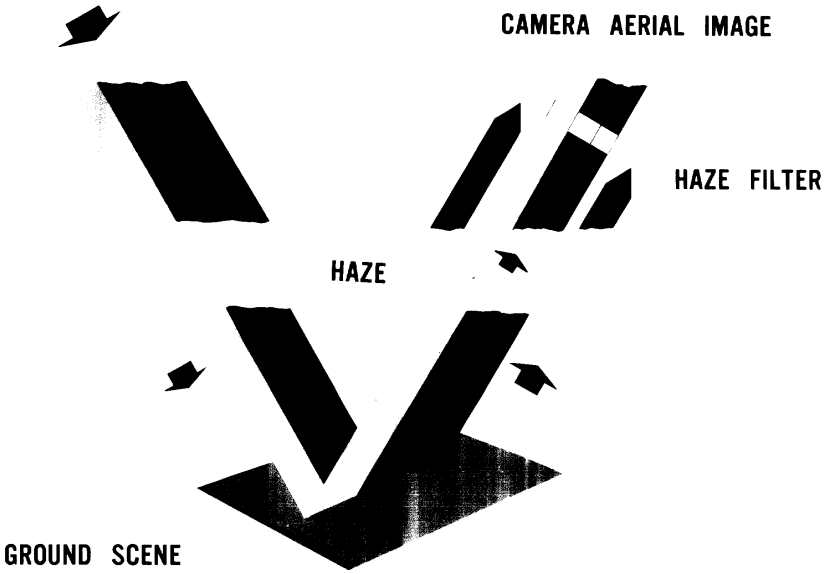

FIGURE 1.

HAZE ATTENUATION

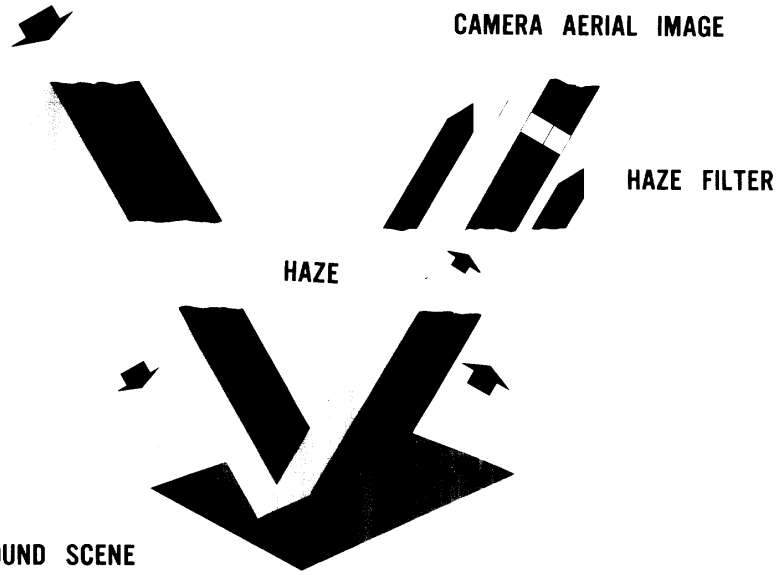

FIGURE 1.

FILM RESPONSE

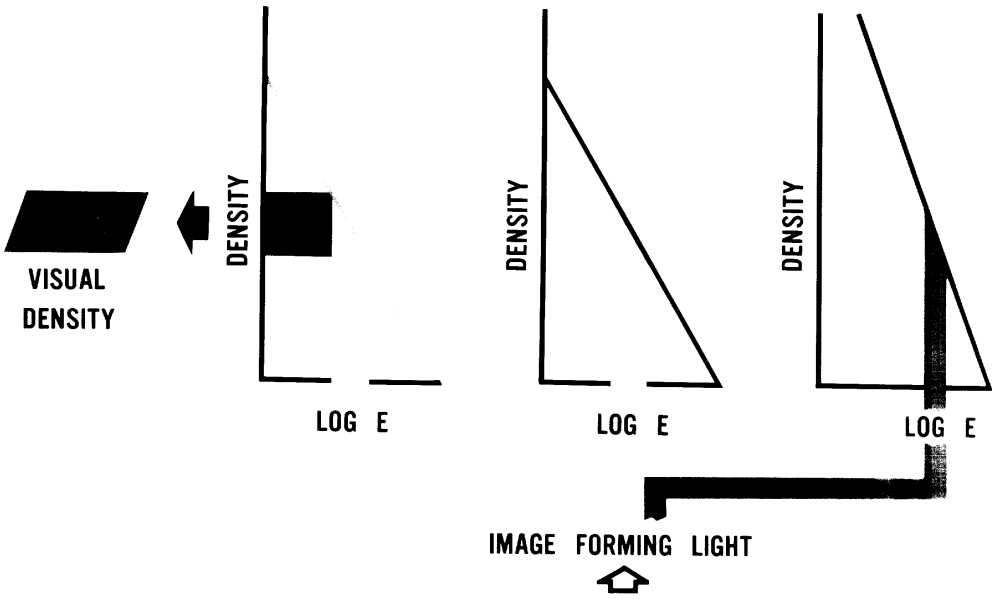

FIGURE 2.

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ACQUISITION ALTITUDE AND FILM SELECTION

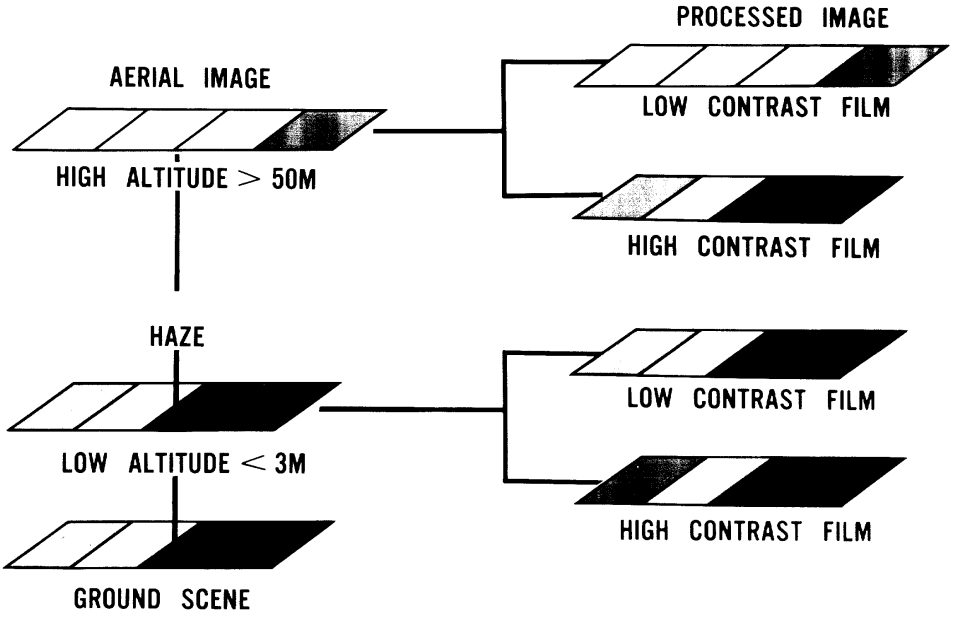

FIGURE 3.
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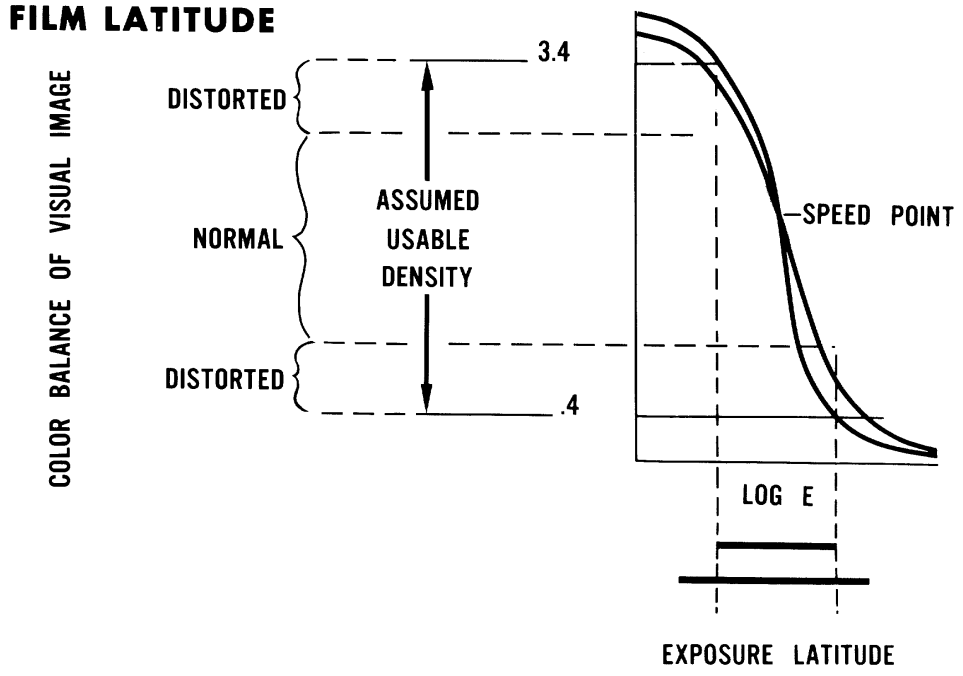

FIGURE 4.

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DISCUSSION

4. Color Duplicating Materials: The customer and contractor agreed at the outset of work that prime emphasis would be placed on the quality of the second generation color positive duplicate. Essentially, the aim was toward the truest or most natural reproduction within the capabilities of the system and available sensitized materials. Specifically, the quality of the copy was to approach as closely as possible what the photo interpreter would see in viewing the scene from close by. Additional guide lines were found necessary in considering the chief factors of color fidelity, contrast and image sharpness. This is because aerial photography normally produces frames with a wide range of scene brightness and taken at various camera angles. Since exposure and color balance are critically affected by such differences, the reproduction quality emphasis was placed on those portions of frames or frame sequences acquired nearest the nadir.

a. Reversal Systems: Good quality second generation color duplicate transparencies have been produced from color positive originals using color reversal materials as a duplicating medium. Again, as previously mentioned, the conditions of acquisition govern the flexibility of this system.

(1) When the original camera film is processed in a system where the resulting image has the same appearance as the original object photographed, the film is called a "reversal" film. The advantage of a color reversal film is that no further stages are necessary to produce a positive image. Color reversal films are of two main groups:

(a) "Incorporated Coupler" films are those which have certain chemicals included in the emulsion during manufacture that greatly simplify the processing stages after exposure. A typical "incorporated coupler" film process consists of a black-and-white first developer, a means of "reversing" the image, a single color developer and appropriate bleach, fix, and washing cycles. The processes are relatively simple and a high quality of

color fidelity can be maintained. The coupler concentration is critical and having it incorporated in the film assists in retaining desired color balance.

25X1 Typical "incorporated coupler" [redacted] Films are those which have the prefix
25X1 [redacted] in the name, such as [redacted] Many films of this group can be processed in the field by the use of chemical kits available from the film manufacturer. It is imperative that the instructions supplied both with the film and the chemical kits be rigidly followed to attain the maximum quality of the color film. There are some "incorporated coupler" films which must be returned to the manufacturer because facilities for processing are not yet generally avail-

25X1 able. [redacted] Special Color Film (Estar Thin Base), Type SO-121, is typical).

(b) "Unincorporated Coupler" films are those which do not have the dye-coupling chemical included in the emulsion during manufacture. The couplers are, instead, part of the chemical processing solution formula. The resulting film process is more complex. A typical commercial process of this type includes a black-and-white first developer, three individual color developers (one for each emulsion layer in the film), three separate means of reexposing the individual layers, plus bleaching, fixing and washing cycles. Since color developer solutions require the coupler as part of the formulation, the mixing and subsequent process usage requires very careful control methods. The entire "unincorporated coupler" process is more complicated and more difficult to control both chemically and mechanically. It is not easily used in field type systems. Kodachrome films are typical of the "unincorporated coupler" type.

(2) Acquisition films used successfully are:

25X1 (a) [redacted] Special Color Film (Estar Thin Base), Type SO-121: Incorporated coupler type.

25X1 (b) [redacted] Aero Film Type 8442: Incorporated coupler type.

25X1 (c) [redacted] Special Ektachrome Aero Film, Type SO-282 (MS): Incorporated coupler type.

25X1 (d) [redacted] II for Daylight: Unincorporated coupler type.

(3) Color duplicating systems used for producing the second generation copies depend upon the density range and contrast of the color original. Few color products show straight-line portions of the three characteristic curves, but have instead continuously changing slopes. This means that film used to make the duplicate must be carefully selected for exposure and color balancing capabilities. Good results have been obtained using films of different contrasts to generate copies for which there are different applications. For selection of a duplicating film, consideration must be given to both its resolution and color balance characteristics. Because available color films may not have both the resolution and color characteristics, a compromise selection may be necessary. This possibility of compromise is greatest for contact printed duplicates and much less for enlargements. Related photographic characteristic curves and data for color materials tested are shown in the Appendix.

(4) A method of selecting a duplicating color film for aerial color originals is best described by the following hypothetical example. Assume:

(a) A high altitude color original has been acquired on Type SO-121 color film (see Appendix for characteristics and data). Measurements made on scenes of the camera color original between the darkest and lightest neutral objects show the following:

Red (max) = 1.60	Green (max) = 1.29	Blue (max) = 1.52
Red (min) = 0.50	Green (min) = 0.38	Blue (min) = 0.52
ΔD_R = 1.10	ΔD_G = 0.91	ΔD_B = 1.00

(b) The scenes were considered to be normal and should have had a brightness ratio of 30 to 1 or about 1.5 density range. Haze accounted for the reduced range and for unequal amounts of the primary colors (red, green, and blue).

(c) To produce more natural appearing results requires that the density range be doubled. Assuming the objects are neutral, the density difference between them must be increased and equalized to maintain the correct color balance. Therefore, the density ranges and gradients of the duplicating material are calculated as follows:

Red: $\Delta D_R = 2 \times 1.1 = 2.20$ Gradient is 2.0 (by requirement).

Green: $\Delta D_G = 2.2$ to equal ΔD_R Gradient is $\frac{2.20}{0.91} = 2.40$

Blue: $\Delta D_B = 2.2$ to equal ΔD_R Gradient is $\frac{2.20}{1.00} = 2.20$

(d) Having determined the gradients and knowing the densities, the film may be selected by calculating the gradients of the potential choices at the mid-density range. The films having the gradients (or contrasts) closest to the requirements would be used. In this case Type SO-121 would be the duplicating film selected, having gradients of approximately 2.10, 2.40 and 2.20 (for red, green and blue respectively).

(5) High Contrast Combinations:

(a) SO-121 and SO-121: Good quality second generation color copies were produced from Type SO-121 high altitude originals using Type SO-121 also as the duplicating medium. As stated previously, light attenuation caused by haze reduces the aerial image brightness range, requiring a high contrast duplicating material. Of all combinations tested, the best contact printed duplicates of high altitude photography were made using Type SO-121 for both acquisition and duplicating.

(b) 8442 and SO-271: Second generation color copies
25X1 on [redacted] Special Duplicating Film, Type SO-271, were made from Type 8442 originals. These copies have good color quality; however, neither Type 8442 nor Type SO-271 have resolution characteristics for more than limited recommendation in high altitude combinations.

(6) Medium Contrast Duplicates: Medium contrast copies also were made from Type SO-121 high altitude originals using Type SO-271. This material is very useful when the color original has recorded a maximum of about 30 lines per millimeter. For contact printed duplicates, however, resolution is its limiting factor. The color balance of these copies is excellent.

(7) Low Contrast Duplicates:

(a) Low contrast color copies were successfully produced
25X1 using [redacted] Film, Type SO-344. This product has an average contrast of about 1.2 and reproduces the density range of the color original very closely. Resolution of Type SO-344 is good.

(b) Low altitude color originals must be duplicated on a material such as Type SO-344 to prevent loss of information in the high and low densities. This could require some compromise between resolution and color balance depending on the resolution of the low contrast duplicating film used. However, low altitude acquisition systems may not require high resolution because of ground scale. An original acquired at the medium altitude of 10,000 feet on Type SO-121 was successfully duplicated on Type SO-344.

5. Negative-Positive Systems:

a. A color negative-positive system of duplicating is similar to black-and-white except that dye images are developed instead of silver images. Color negatives and print materials usually have incorporated dye couplers. Processing is relatively simple, consisting primarily of a

color developer, stop bath, bleach, fix, and the necessary washes. Processed color negative images will be of little value to the photo interpreter because dye systems used in color negative films are in complimentary colors designed for compatible print materials, but not the human eye. Reliable identification of target colors by direct examination of the negative should not be expected. Target images, of course, can be discerned to save time in the selection of frames for printing.

b. Color negative acquisition was not made at high altitude because of resolution limitations.

c. Duplicating systems have been successful. Using [redacted] Special Ektacolor Aerial Film, Type SO-276, [redacted] X, and [redacted] Color Internegative Film, color negatives were produced by contact printing from Type SO-121 color positive originals. 25X1 25X1

(1) Reversal and negative-positive systems together can provide the community with color positive duplicates and compatible internegatives both made directly from the original to retain maximum resolution. The contact printed internegative provides a means of going directly to third generation transparency or reflection prints at any desired enlargement practical for the system.

(2) A continuous contact printer was used for the internegative exposing stage and processed through the Speltron, a color negative processor.

(3) The selection of which color negative material to use is dependent upon the available processing equipment and printers.

(4) Type SO-276 and [redacted] X are materials having an antihalation protection coating which is leached out in processing. These products can, therefore, be processed easily in a C-22 color process system. 25X1

25X1 [redacted] Color Internegative Film has a removable jet backing on the film support. This must be removed in the processing cycle, and thus requires

special buffing racks for removal. Despite some processing complication to remove the backing, the better resolution characteristics of this [redacted] color film are desirable. Both [redacted]X and Eastman Color Internegative Films have good low contrast control for duplication purposes. Results of testing with Type SO-276 showed no significant advantages in comparison with results from [redacted]X, and therefore no further mention of Type SO-276 will appear in this report.

25X1

25X1

25X1

(5) Data sheets and characteristic curves are included in the Appendix.

6. Enlarging Systems:

a. Intelligence briefing aids and/or enlargements for P. I. study have been partially explored for usable systems. Six of the seven systems tested (see Figure 5) provided excellent to poor enlargements. The quality depended upon the generation of the final color positive transparency and the stage or stages at which enlarging occurred. A required consideration is the availability of the acquisition color positive original. As shown in Figure 5, excellent quality and resolution are possible, but some of the systems were considered impractical.

b. Equipment limitations prevented the preferred use of additive printing with narrow band filters in the enlarging stage. Thus all work was accomplished using the subtractive printing method. These two methods are illustrated and discussed in the section on Color Printing Equipment.

c. The negative materials used in the testing were processed using laboratory "sink" processing systems until late in the program when a continuous negative color processor became available. As described previously (Negative-Positive Systems), contact printed internegatives were produced on three products. Excellent quality and resolution were retained in enlargements up to 17X (maximum tested).

Figure 5

SYSTEM STUDY FOR ENLARGED COLOR DUPLICATES

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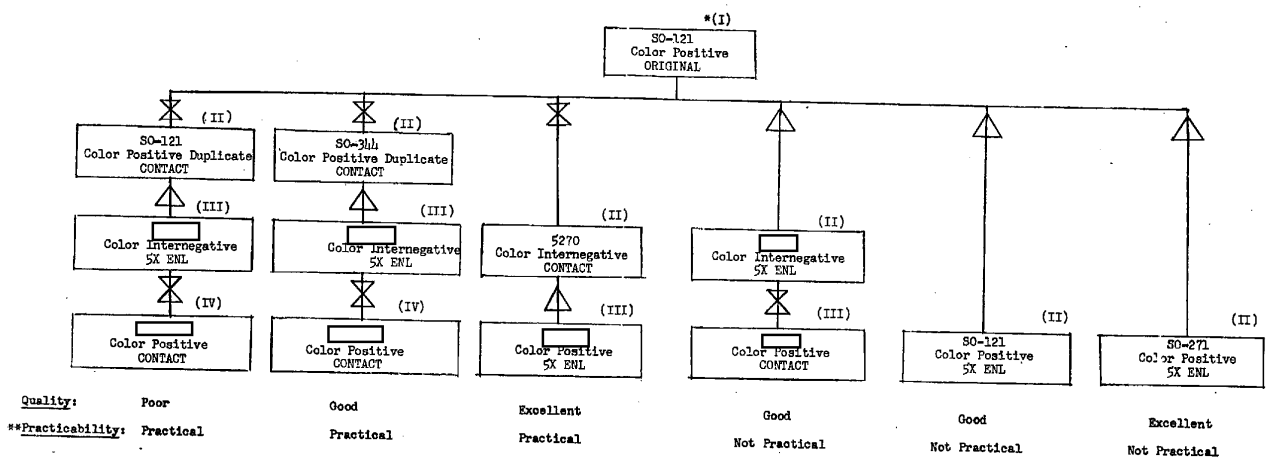

**Practicability rating assumes all community sub-sections do not have access to the color original when needed.

Material Legend

SO-121: Special Color Film (Estar Thin Base)
SO-271: Color Duplicating Film
SO-344: Film
5270 : Color Internegative Film
KEI : Internegative Film
KEP : Print Film

Contact Printing

Enlargement Printing

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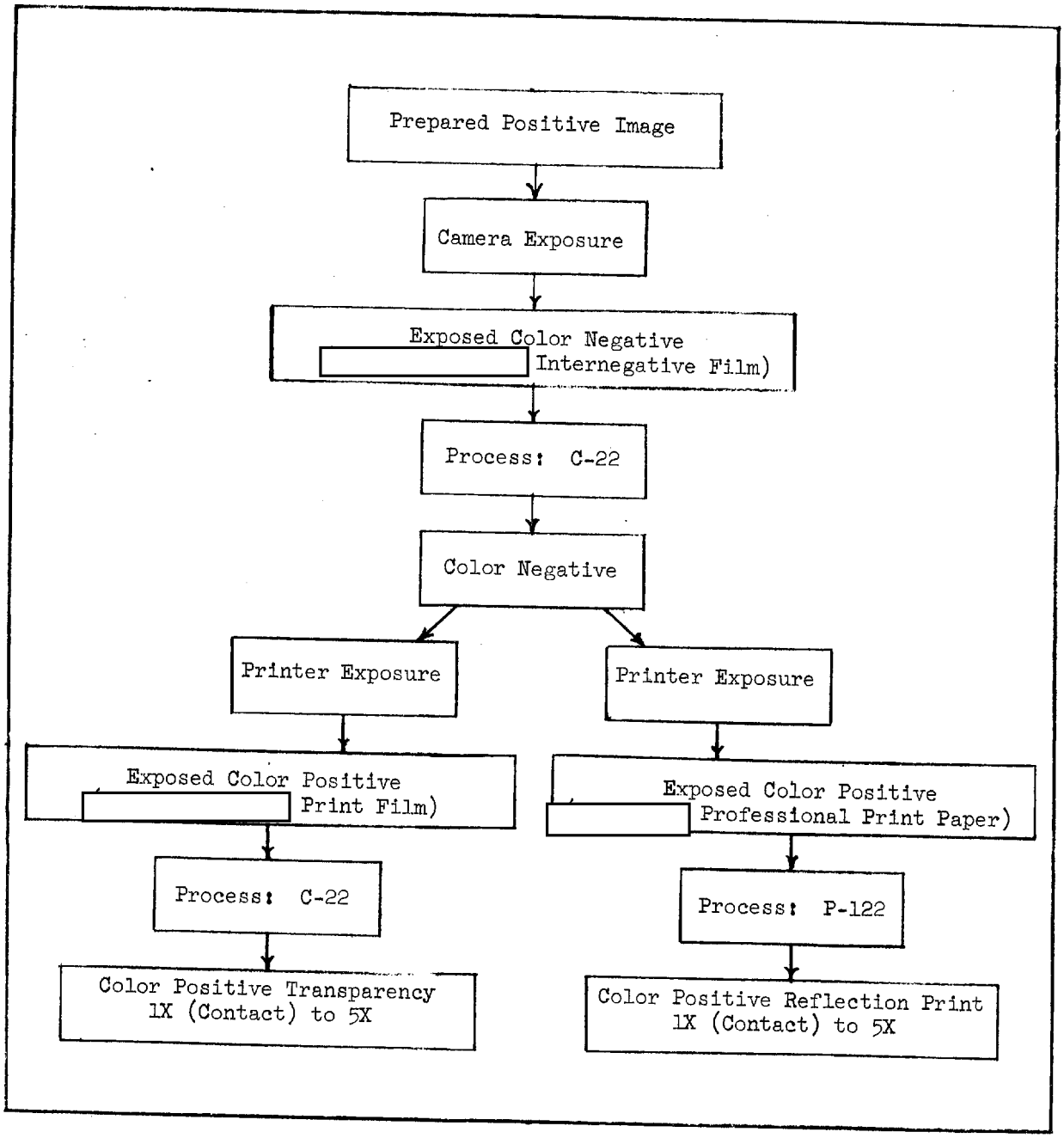
d. Enlarging from the color positive original directly to a 3X internegative provides a wider selection of materials because films of lower resolution capability may now be used. For example, [redacted] Ektacolor Internegative Film has limited value in contact printing but can be considered as an enlarging medium. 25X1

e. Artist rendered briefing boards have been successfully copied using industrial studio techniques. (See Figure 6.) The system shows only a common color negative-positive system. There are other systems which can be used for color positive originals which were not included for test effort as the systems are established and data published. Adequate description of these 25X1 other systems are found in the [redacted] Graphic Arts Handbook. This is a loose-leaf publication available in up-to-date form from graphic arts dealers. It is important to note, however, that artist materials may cause some difficulty in color reproduction. The main sources of difficulty are usually caused by the color temperature and spectral distribution of the lighting, and the artist's color not being recorded on the film as the human eye sees it. Response of a color film to colors available for briefing aids can easily be determined by a color photographic check.

f. Stereoscopic Effects: The high altitude missions were flown 25X1 with Type SO-121 color film and [redacted] High Definition Aerial Film (Estar Thin Base), Type 4404 -- a black-and-white negative material -- simultaneously exposed in paired cameras. From positive prints of these acquisitions, stereoscopic viewing was possible. (See Figure 7.) Contact color positives were made on two materials. These were Type SO-121 and SO-344. When high contrast color scenes (Type SO-121) are viewed with the normal black-and-white scenes, medium color saturation is seen with excellent sharpness. This effect thus gives the sharpness of the inherently sharper black-and-white positive plus the color signatures from the high contrast color duplicates. When viewed stereoscopically, the normal black-and-white scene and the low



25X1

25X1

25X1

Figure 6. NEGATIVE-POSITIVE COLOR REPRODUCTION SYSTEMS
(For Reproduction of Briefing Charts and Intelligence Enlargements)

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COLOR/BLACK-AND-WHITE STEREO SYSTEM

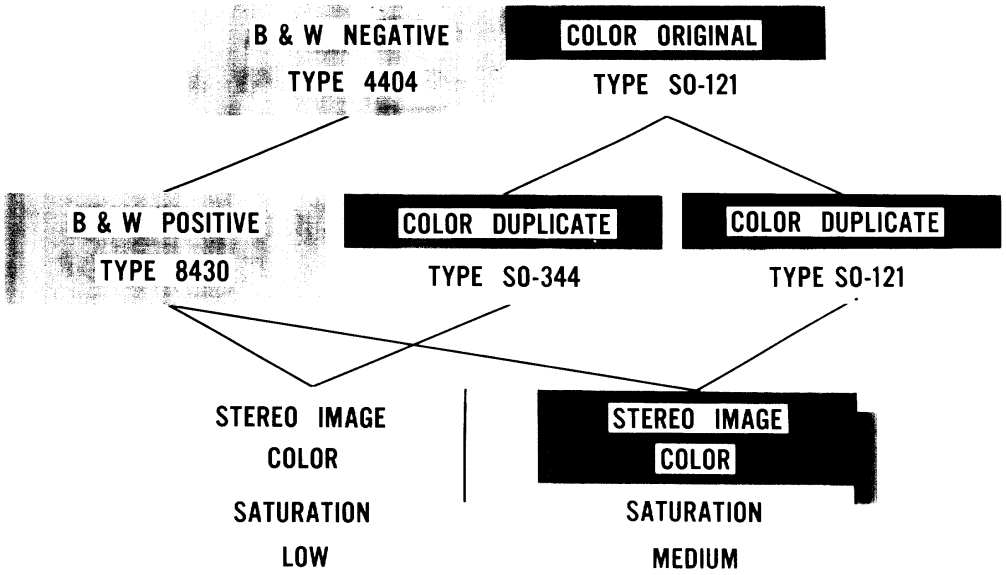

FIGURE 7.

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contrast color scene (Type SO-344) provide insufficient color saturation. Stereo viewing with color images on both sides produce the maximum color saturation and signatures of target areas. However, for the systems studied, the apparent resolution is greater for color/black-and-white pairs. (See Figure 8).

7. Color Printing Equipment: (NOTE - No equipment was designed, fabricated, modified or otherwise provided under this project. Printers discussed in this section, as well as processors and other hardware discussed in later sections, were conceived and developed under other programs.)

a. Contact Printers: High-speed continuous contact printers have been used successfully for printing color duplicate positives, color internegatives and black-and-white duplicate negatives. Both additive and subtractive methods of light-filter combinations were tested. (See Figure 9).

(1) Additive Printing: Narrow spectral band filters (red, green and blue) were selected to match the peak sensitivities of the emulsion layers in the duplicating film. The three filters were positioned in separate apertures, and exposure balance also achieved separately for each color by the use of neutral density filters. Duplicates produced by additive printing, as compared to subtractive printing, gave good images with colors of better hue, brightness and saturation. This is the preferred method for printing color to color or color to black-and-white, where maximum information retention from color originals is desired. (See Part A of Figure 12). It is also superior for control of color balance. The method applies to both contact and enlargement printing.

(2) Subtractive Printing: With this method, color and exposure balance was obtained by using Kodak color correction and neutral density filters over a single aperture. Good quality color copies were obtained; however, interlayer color image effects were apparent and when printing the color original onto a panchromatic black-and-white material, there was a

COLOR/COLOR STEREO SYSTEM

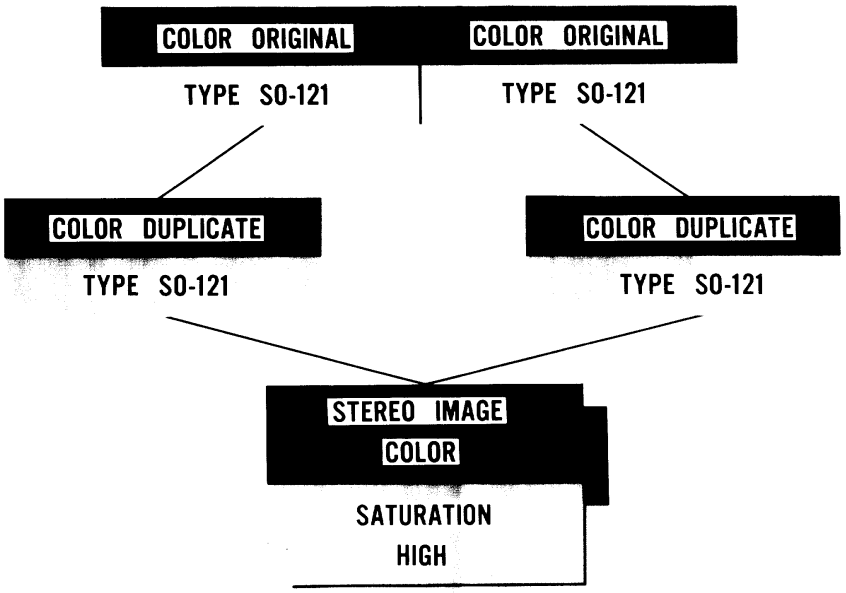

FIGURE 8.

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REPRODUCTION SERIES* COLOR TO COLOR

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SO 121: [ ] SPECIAL COLOR FILM (ESTAR THIN BASE)

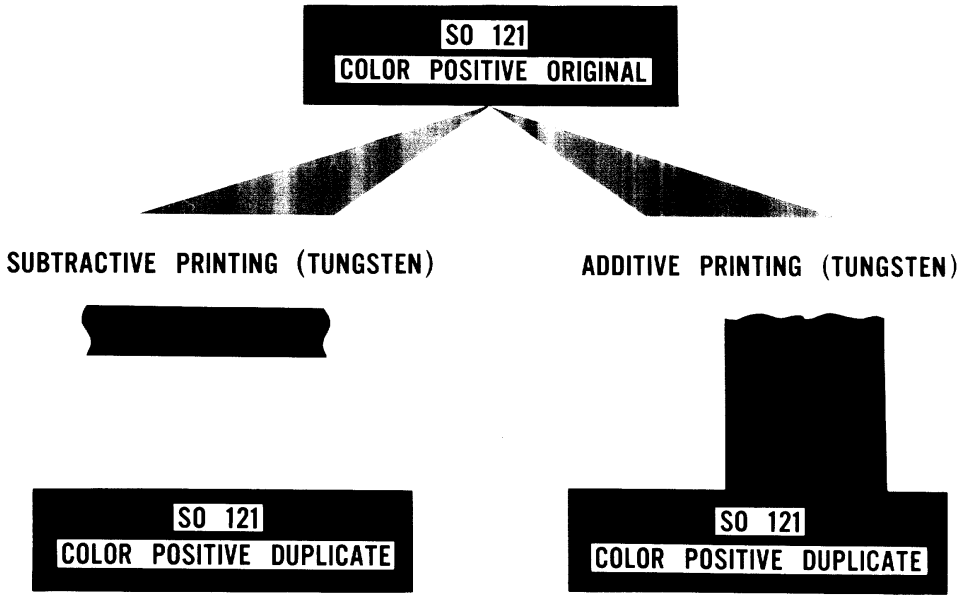

FIGURE 9.
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demonstrated loss of some color target information. (See Figures 10, 11 and Part B of Figure 12). This method also applied to both contact and enlargement printing.

(3) Testing was accomplished on two printers:

(a) Niagara Printer: Additive color printing was done on a Niagara printer specially equipped with a tungsten source and a simple modification of the aperture. The one-inch aperture was reduced by a photographic mask to three separate 0.25-inch apertures. Narrow band filters of red, green, and blue were then positioned -- one in each 0.25-inch aperture. Color balance was controlled by adding or removing neutral density filters over each aperture. This was done for printing duplicates of Type SO-121 originals onto Type SO-121 color film. Filters used were:

1. Red: Wratten No. 29 with Corning Heat Absorber.
2. Green: Wratten No. 99.
3. Blue: Wratten No. 35 with Wratten No. 47B.

The Niagara Printer can be operated as an additive printer at 82 feet per minute when camera type color materials are used as a duplicating medium. Typical examples are Types SO-121, SO-276 and [redacted] X. The Niagara is not practical as an additive printer for all duplicating films. Some of these films are slower in speed by as much as 2.00 Log E compared to the type of films used in cameras. To print such materials by the additive method would reduce Niagara printer output by more than 95%. Typical examples of the slower speed duplicating materials are Type SO-271 and [redacted] Color Internegative Film. 25X1 25X1

(b) Colorado Color Printer:

1. Initially, subtractive color printing was done on a Colorado printer. The Colorado is a Niagara type printer with a specially designed lamphouse and a tungsten light source. The principle of subtractive printing is achieved by individual dial control of cyan, magenta, and yellow

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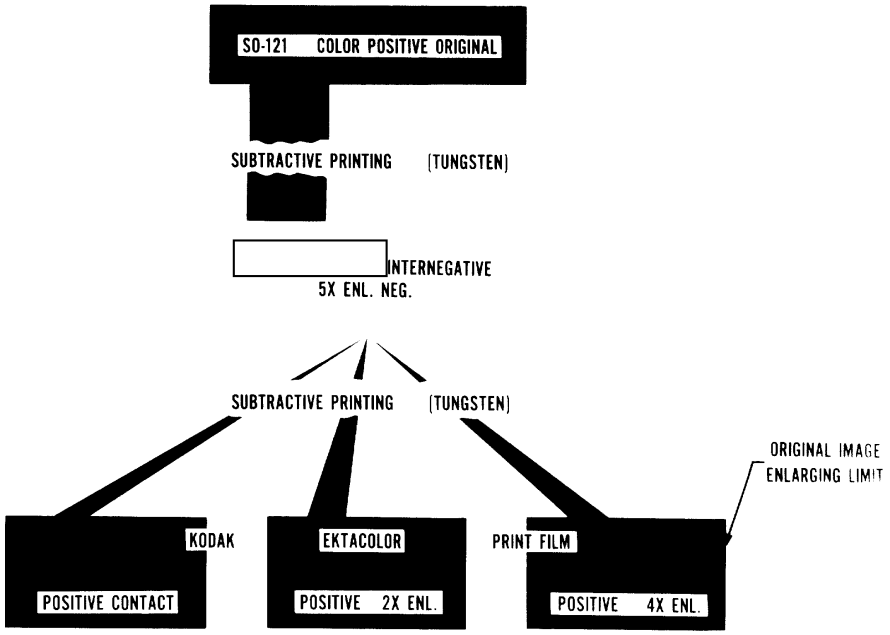

FIGURE 10.
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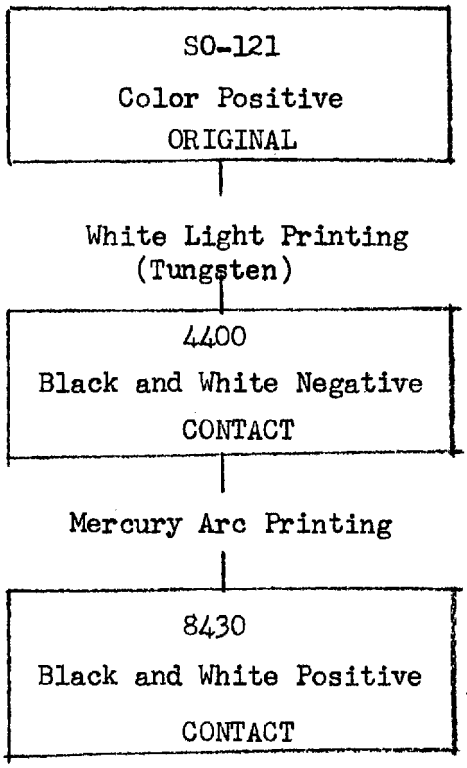
REPRODUCTION SERIES: COLOR TO BLACK AND WHITE



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SO-121: [redacted] Special Color Film (Estar Thin Base)

4400 : Panchromatic Aerial Film (Estar Thin Base)

8430 : Fine Grain Aerial Duplicating Film

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Figure 11

COLOR PRINTING METHODS

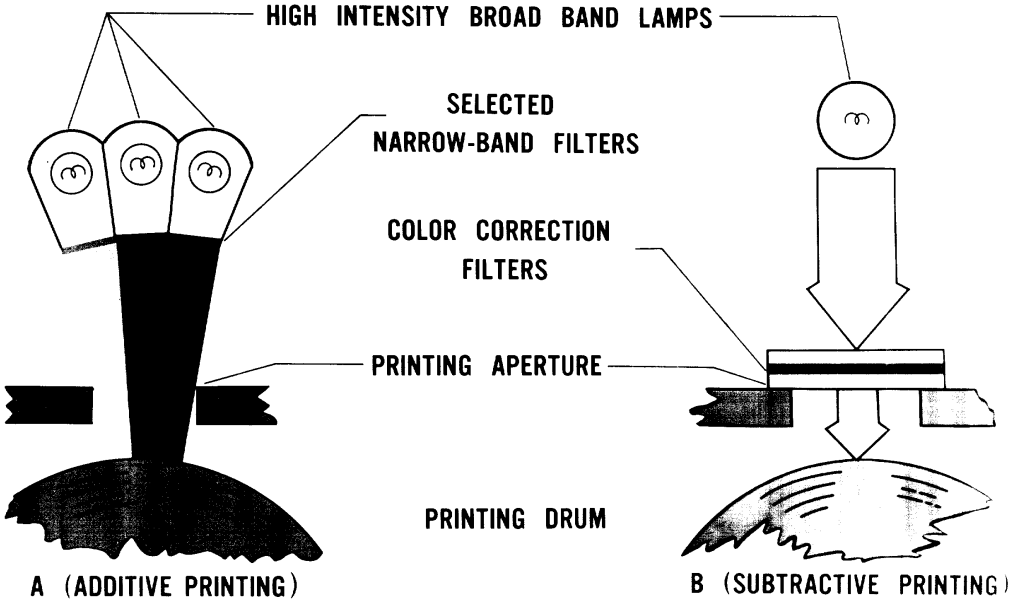

FIGURE 12.

filters and neutral glass variable filter wedges. The resulting total light quality is then measured by a Quantalog densitometer which is an integral part of the printer. Because this method of control is still not fully appraised, it was not used during this study as a method of subtractive printing.

25X1 2. Color balancing for subtractive printing was accomplished by using [redacted] color correction and neutral density filters over the entire printing aperture. Good quality color prints were obtained, but here again, the quality was not judged as good as that for the additive printing method. This conclusion is related to the basic methods and should not be attributed to the printers used.

3. This unit was also used for additive printing by setting all color correction wedges on "zero" and inserting the "tri-color" narrow band filter pack. The results from the Colorado as an additive printer compared favorably to those from the Niagara.

b. Step Printers: (Step-and-repeat contact printers for color materials are being designed).

(1) Experimental Testing: A modified "Morse" printer equipped with a high intensity tungsten light source was tested using subtractive color correction filters. The printer will accommodate a 9.5-inch width of film and expose a 20-inch length in one step. Experience was limited to contact printing multiple copies of selected color positive original frames and selected color negatives. The originals were 70mm and 9.5 inches in width. Estar thin base and standard base materials were used. Excessive exposure times were necessary for most materials because the single lamp provided insufficient intensity over the large field. Thus reciprocity effects were observed in some cases. Problems were encountered in registration across the width of the original and duplicating materials. This problem was aggravated by lack of adequate supply and take-up assemblies for both the original and duplicating stock.

(2) Design Requirements: From the above experience and the lack of commercially available equipment, the following requirements will have to be satisfied for a step-and-repeat printer (not the "Morse" printer).

(a) Good flat bed contact-immersion printing may be required to eliminate Newton rings.

(b) Capability of handling any width from 70mm to 9.5 inches.

(c) To verify frame numbers with minimum raw stock usage, the selected frames should be conveniently viewable by the operator.

(d) The printer should have sufficient light intensity for exposing color originals or duplicating films, similar black-and-white types, and various types of color and black-and-white paper print materials.

(e) Repeated printing of a single color frame with a high intensity light source requires a means of cooling the original to prevent fading of dye images.

(3) Other desirable features which should be incorporated where possible are as follows:

(a) Printer cycle time per frame should be kept to a minimum to provide maximum production capability.

(b) Incorporate within-frame tri-color electronic masking or dodging to improve color and density differences caused by camera angle, solar altitude, and haze effects.

(c) Specific frame recall-information or features of this type may become available in the future. If this occurs, new printers should include them if feasible.

c. Enlarging Printers: For maximum utilization of color in aerial reconnaissance, multiple copies and some enlargements must be generated. Photographic materials are included in this discussion only to the extent necessary to provide a means of evaluating optical-mechanical considerations for

enlargers. Tests and practical experience strongly indicate that enlargements should be made directly from the original to avoid losses of image sharpness, color fidelity and tone reproduction. The production of enlargements from second generation contact printed color positives is not recommended. The best enlargements can be made directly from the color original. This system is impractical for simultaneous community group efforts. Internegatives made from the color positive original, and delivered with the color positive duplicate, would minimize this problem. The internegative would provide maximum retention of image detail and color fidelity from which subsequent enlargements could be produced.

(1) Step enlarging has been accomplished successfully. Commercial enlargers are available which incorporate the step method for selective frame-by-frame printing. The majority offer wide selections of capabilities and accessory items. Test work was accomplished using two commercially available enlargers equipped with color-corrected lenses. Illumination falloff, off-axis unsharpness, subtractive printing, and long exposure time were the major problems. One of the units, the [redacted] 10-20-40X enlarger with a 19X color-corrected lens, produced enlargements of excellent quality.

25X1

(2) High output continuous enlarging printers capable of handling 70mm original material are not available. The basic principles are known, but the design problems are complex.

(a) For rapid enlarging of selected frames or areas, maximum quality can be retained by providing the community with a continuously enlarged color negative made directly from the original. Enlarged color positive copies could also be provided if desired.

(b) Exposed raw stock up to 9.5 inches, generated by a continuous enlarger, could be processed on present continuous equipment.

(c) A continuous enlarging capability would be highly desirable to gain the maximum benefits from color materials. In providing

this capability, problems of equipment design must be considered. Continuous enlarger design problems currently recognized include:

1. Isolation from sources of vibration.
2. Uniformity of light over the entire aperture.
3. Range of enlargement.
4. Color-corrected optics.
5. Mechanical film speed ratios of print master to raw stock.
6. "Tri-color" light sources.

(d) For dual purpose, step-and-repeat enlarging capability would provide versatility. Electronic "dodging" or masking should likewise be considered.

(e) A contact printed internegative system now available does not provide the best response to community needs. Resolution of the enlargements are limited by the inherent resolution of internegative materials currently available.

d. Light Source Performance Requirements: Light sources for printing color originals onto color and/or black-and-white materials have specific design requirements. These vary with the purpose of the equipment of which they are a part. Applied design considerations in the general scope of color printing include the following:

(1) High energy output for the red, green, and blue portions of the visible spectrum. (A high energy lamphouse is currently in the design stage).

(2) Selection of a source with the coolest operating temperature to reduce or prevent dye fading of the printing master.

(3) Selection of a source with long life and good stability characteristics.

e. 1:1 Optical Printing:

(1) Continuous printers of this type are not available for 70mm to 9.5-inch films.

(2) Despite the advantages of optical printing, e.g., adaptability for within-frame color correction, the optical design problems are formidable.

(3) Unless a nearly "perfect" optical system could be designed, there is a strong danger of loss in image quality.

8. Color Processing Equipment:

a. Continuous Machines: The two color processing machines discussed are the reversal type and the negative-positive type:

(1) Color Reversal Processors: Two machines are available for test work. One is designed to provide a test facility and limited production capacity for color films with incorporated couplers [redacted] The second provides similar capabilities but is designed for films with unincorporated couplers [redacted]

25X1

25X1

(a) Because of the success and simplicity of processing Ektachrome compared to the complexity of [redacted] processing, relatively few reproduction tests were completed on the second processor ("Ragdoll"). In view of this, provisions are being made to operate the Ragdoll as an [redacted] processor when needed.

25X1

25X1

(b) The color reversal processor ("Grafton") for [redacted] products is a sinuous path, deep tank, machine with recirculation systems for six of the ten solutions. The majority of test effort was with this processor. The machine is capable of processing either thin base acquisition film such as [redacted] Special Color Film (Estar Thin Base), Type SO-121, or standard base material such as [redacted] Film, Type SO-344. These films also differ in that Type SO-121 has an antihalation dye in the backing which leaches out during the process cycle, whereas the SO-344 has a removable antihalation

25X1

25X1

25X1

25X1

backing (removable-jet) which requires auxiliary chemical and mechanical treatment in processing for its removal.

(c) The Grafton accommodates widths of 70mm to 9.5 inches and operates at five feet per minute. Although the speed of the machine is relatively slow, single-strand 9.5-inch color duplicates can be contact printed from three 70mm color originals (one at a time) to increase the processing output by a factor of three. The 9.5-inch strand then must be slit and trimmed to the 70mm size as a post-process operation. The many thousands of feet of [redacted]-type films processed during this study were run on this machine. Both 70mm and 9.5-inch materials were processed with generally excellent results.

25X1

(2) Negative-Positive Color Processors: A color negative-positive continuous processor ("Speltron") has been tested using the [redacted] C-22 process and applicable photographic materials. Negative films can be processed on this machine at 2.5 feet per minute. To process reflection print material (paper base), a [redacted] Dryer-Glazer will be installed as the final station. The advantages of high resolution and contrast control characteristics offered by [redacted] Color Internegative Film can be obtained by incorporating a station to remove the rem-jet backing.

25X1

25X1

25X1

(3) Design Requirements - Continuous Deep Tank Color Processors: Experience gained from existing available equipment further pointed up the need for the following design requirements:

(a) Color processors should be designed for specific processes. Multi-process processors usually impose limitations in quality and/or production output. (Example: Solution-to-solution crossover times can and do cause undesirable chemical and photographic control problems).

(b) Deep-tank color processors should have temperature controls capable of maintaining ±0.5°F in all chemical solutions. Washes need not be controlled to this narrow tolerance. Use of the same water for

both solution temperature control and washing has limited application if high quality is to be maintained.

(c) Solution agitation is critical in color processes and must be closely controlled to the required levels of agitation.

(d) Processor top rollers should be submerged except for crossovers. Submerged top rollers will prevent aerial oxidation, reduce the tendency for streaking, and provide more consistent solution times.

(e) Adequate flow rate instrumentation is mandatory to insure a high level of quality. This applied to all replenished and re-circulated chemical solutions and to wash water.

(f) Temperature indicating-recording instrumentation should be incorporated at the design stage. Temperature variations cause undesirable shifts in color balance and speed. For control of high output systems, dynamic process conditions require immediate transmission of temperature data to the control area outside the machine room.

(g) Speeds of 20 feet to 40 feet per minute (single-strand of 9.5-inch width) should be considered as a design aim.

b. Roller Transport Machines:

(1) Expected Capabilities: The roller transport principle adapted to color processing has some unique features and advantages. These are:

(a) The principles of machine design have been highly successful in both the X-Omat and Versamat type processors.

(b) Efficient agitation required in color processing may be provided by the "squeegee" like action of the submerged rollers in each machine rack. This action occurs at each of the film support rollers and requires that careful consideration be given to safeguards against possible film damage.

(c) Solution volumes are small on a per tank basis. This is an advantage for maximum use of chemicals, but may require high rates of replenishment because of the relatively rapid chemical exhaustion rates of most color systems solutions.

(d) The modular design permits the assembly of basic components for "tailor-made" processing of many photographic materials.

(e) Field military units, presently equipped with black-and-white systems, might reduce logistical support problems by using interchangeable parts for multi-purpose equipment.

(f) Transparency and reflection print materials could be finished as either continuous strips or sheets.

(g) Properly designed equipment should be simpler to operate and require fewer highly trained personnel for the processing operation compared to other continuous color processing systems.

(2) Expected Limitations: Study of the system chemistry and associated mechanical conditions is continuing. It is important to point out that the use of a roller-transport color processor prohibits solution time changes as a means of correcting known errors in the exposure of the film. (This is not a serious limitation because time changes are discouraged in favor of proper camera exposures.) Exposure correction by temperature variation, although possible, will cause undesirable shifts in color balance. Variation of process chemistry to correct erroneous exposures should be discouraged. There are no simple means or instantaneous sensing devices to alert the operator for all the dynamic chemical conditions of the system.

c. Drum-Type Color Processors: Continuous drum-type processors are not commercially available. Prototype equipment has been designed for black-and-white film processing but further work is needed in this field. The complexity of drum systems is such that continuous color processing is

not foreseeable in the near future.

d. Processors, Small Scale:

(1) Applicability: While this type of processing is primarily limited to small scale operations, 70mm film up to about 25 feet in length were satisfactorily processed in the "Nikor" reel-tank unit. "Nikor" units are available with roll film capacities to 100 feet; however, processing of such lengths was not done at the contractor's facility. Sheet film and paper materials are readily processed in conventional "off-the-shelf" basket-type equipment.

(2) Testing: Test work and systems review in this area of color processing were accomplished using [redacted] kit processes where possible. 25X1
Pre-packaged color chemicals provided the highest assurance of quality and repeatability. Equipment-chemical systems used were:

(a) Basket-tank: E2/E3, C-22, P-122, and [redacted] 25X1
Color Negative.

(b) "Nikor" reel-tank: E2/E3, C-22, [redacted] Commercial and Modified ME-4. 25X1

(c) Air Force B-5-tank: E2/E3.

25X1 (d) [redacted] Rapid Color Processor, Model 16K (high agitation): C-22, P-122.

25X1 [redacted] Color Negative, [redacted] Commercial, and ME-4 processes are laboratory mixed; all others are mixed from process kits. All process steps of kit processes normally are designed for one temperature only in the wet cycle with various tolerances for each stage. Exposure errors are usually "corrected" by time variation although gross changes may require chemical adjustment. For maximum quality, properly exposed film is a requirement. Also for maximum quality, manufacturer's instructions must be followed explicitly.

(3) Results: Of the various systems tested, the following observations are noteworthy:

(a) Color film processed in the "B-5" system, while acceptable, demonstrates a streakiness and nonuniform development. This is inherent in the design because chemical solutions are "trapped" within the film convolute.

(b) In these small-scale systems, all parts of the film do not receive the same degree of agitation -- this is a function of the film lengths and widths involved.

(c) Thin base films such as SO-121 are difficult to load in a "Nikor" reel.

(d) Processes dependent on operator-agitation (lift and drain) may demonstrate different speeds and color balances. Skilled, experienced personnel have difficulty in total darkness to determine accurately the passage of time. While process stages are easily timed, control of operator-agitation cycles is most difficult. A "process programmer" was used to provide signals for more accurate cycle timing. The product quality was thus improved.

(4) Timing Device: The "process programmer" was devised prior to work on this project as a means of signalling the three basic movements performed by the operator in a totally unmechanized processing cycle. These movements are "UP", "DOWN", and "MOVE in a horizontal direction". By punching a 35mm machine leader at selected intervals and positions, timed audible or visual-audible signals are programmed for the movement to be performed. Leaders can be punched readily for any process. The device now is being further tested for timing immersion of sensitometric process control strips concurrent with the processing of long length, uncut originals. (See Figure 13).

PROCESS PROGRAMMER

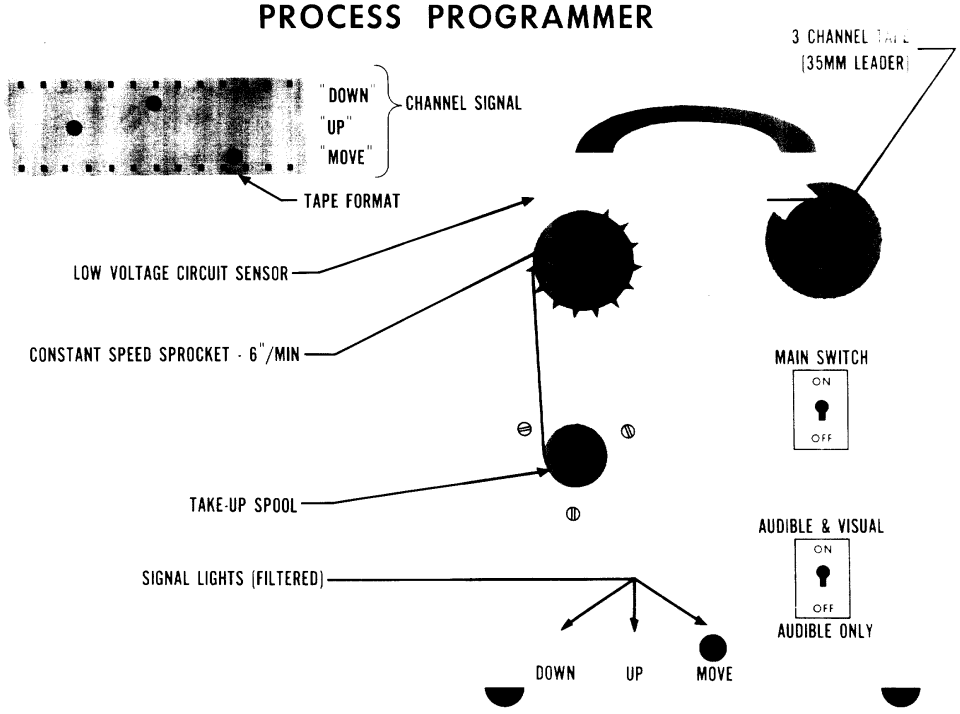

FIGURE 13.
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e. Viscous Negative-Positive Color Processors:

(1) Advantages: The use of a frame-by-frame viscous color negative processor would have many advantages. Among these are:

(a) More constant chemical strength. (Single-use viscous developers eliminates replenishment for a large chemical inertia system, thus reducing potential process drift.)

(b) Minimum solution handling.

(c) Wider tolerance in temperature control.

(2) Background knowledge is limited to successful black-and-white systems. To date, viscous developers have not been formulated for the processing of aerial color negative-positive materials. Problems are:

(a) Handling and storage (stability keeping) characteristics are not known.

(b) Viscous processed image stability will need study. These problems would apply to any new color processing system.

(3) Feasibility study is necessary as a first step toward solving the above problems, if the advantages of a viscous approach are desired for color processing.

9. Post Processing Equipment:

a. Type of Equipment Discussed: Finishing equipment for color reproduction materials may be divided into two categories:

(1) The type of equipment for long lengths of film and paper.

(2) The type for sheet materials.

Finishing equipment for sheet material will not be reviewed, since there is available literature to cover most normal situations. Dealer catalogues, 25X1 circulars and handbooks [redacted] provide a good sampling of the available equipment.

b. Cleaning:

(1) Cleaning of long length color original and duplicate transparencies presents special problems. Cleaning tests have been conducted on Types SO-121 and SO-271 film. Tacky roller cleaners, while effective in removing air-borne dust, and similar particles, have sufficient adhesive power to remove emulsion areas of pin hole size. The cause is related to softer emulsion surfaces on some color products. Tacky roller cleaners are not presently recommended for either of these films. Improvements in films or processing aimed at hardening the emulsion surface may resolve this problem at a later date.

(2) A continuous film cleaner using solvent application was tested with Type SO-121. While a slight pink buildup of residual dye appears on the buffing or cleaning roller, densitometric data indicated less than 0.02 magenta density loss after 25 passes through the machine. The film cleaner 1,1, 1 trichloroethane, was the same as used for current black-and-white materials. No special precautions were necessary. Tests are underway to determine if color films cleaned with these solvents are affected after prolonged storage in sealed containers.

c. Lubrication: The lubrication of color films in widths of 70mm to 9.5 inches has not been investigated. Requirements need to be established.

d. Titling:

(1) Titling of color positive films has been accomplished using custom built black-and-white equipment. Products extensively handled were Types 8442, SO-121, SO-271 and SO-344. Color negative products have not been tested to date; however, no problems are expected.

(2) Current titling methods require separate handling for each film length. Color positive films have maximum density around the frame format. Thus, titling the original film prior to printing the dupli-

cate is not possible because the title cannot be printed through the maximum density areas. The original and all successive duplicates must therefore be titled as repeated operations. With this method, the possibilities of human error in keeping all frames of all copies correctly titled are increased in relation to the number of copies required. An edge flashing technique is being investigated on another contract. This may result in a solution to the problem, by providing a clear edge for titling.

e. Slitting: Slitting of processed color film from wide formats that have been multi-parallel contact printed is a practical means of increasing output from the processing machine. The use of Estar Thin Base (Type SO-121) for duplicating has been successful for this purpose. There have been some minor problems in precision slitting with current pilot stage equipment. These problems are expected to be solved.

10. Viewing Equipment:

a. General Information:

(1) Valid identification of target color signatures requires established guides for the available color systems. The requirement for controlled viewing conditions is of great importance to photo interpretation.

(2) Proper viewing conditions for color films cannot be overemphasized. Two main factors contribute to the observer's impression. These are the correct ambient room lighting conditions and the viewer light source. Both factors are influenced by intensity, uniformity, and spectral distribution. While new data are constantly being developed which may alter present recommendations, the viewing conditions should adhere to those outlined by the American Standards Association. The publication is PH 2.23-1961 entitled "American Standard Lighting Conditions for Viewing Photographic Color Prints and Transparencies."

(3) There is considerable adaptation by the human eye to differences in viewing conditions. Ample treatment of this subject may be

found in chapters three and four of Principles of Color Photography. This book was authored by Messrs. R. M. Evans, W. T. Hanson, Jr., and W. L. Brewer. It was published by John Wiley and Sons, N. Y., 1953, and carried Library of Congress Card No. 53-6722. Despite this ability of the eye, however, viewing conditions should be established to help the operator relate color signatures to known targets. Good viewing conditions will lessen the effort to compensate for color and density changes, promoting more rapid and complete information extraction.

b. Transparencies:

(1) Color reproduction materials and methods which have been and are used to provide target color signatures necessitated the establishment of additional "ground rules." These rules will require revision as community requirements become more positively defined. Color reproduction of scenes acquired at or near the nadir point are used as the aim. Equipment limitations prevent using a broader reference in long film lengths. Oblique scenes are not acquired under these conditions and therefore show varying degrees of density and color balance. The photo interpreter must then either mentally "correct" for these differences, or use mechanical-optical devices that will assist him.

(2) All optical devices and aids used by the photo interpreter in examining color products must be color corrected. Microscopes, magnifiers, projectors and stereo viewing devices are included. The degree of color correction will depend upon the intended use of the device.

(3) Best ambient room conditions include flat neutral gray walls with 18% - 30% reflectance. Color temperature of ambient lighting should be 3800 ±200°K and of variable intensity to provide incident diffuse light equivalent to 10% - 25% of the transmitted light.

(4) A survey of available equipment and typical characteristics are given with their color temperatures and intensities as follows:

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Equipment Item	Color Temp: (Kelvin)	Intensity: (Ft-Candles)
25X1 [redacted] Avlite Standard Viewer, Model T-214:		
Intensity Switch on HIGH	4000°K	325
Intensity Switch on LOW	4000°K	260
25X1 [redacted] Avilite Standard Viewer, Model T-240:		
Intensity Switch on HIGH	4000°K	360
Intensity Switch on LOW	4000°K	192
25X1 [redacted] Motorized Film Inspection and Splicing Table, No. 1-214-R-001	4300°K	593
25X1 [redacted] 55-Inch Film Viewing Table, No. 1-200-R-001 (all table lamps "ON")	4500°K	600
25X1 [redacted] Stereo Viewer for 9-inch x 9-inch and 9-inch x 18-inch Roll Film	4300°K	128
25X1 [redacted] Viewer, Background Projector:		
Projection at 5X	*	28
Projection at 15X	*	20
Projection at 30X	*	6

Measurements were made using a "Spectra Color Temperature Meter" [redacted] 25X1
25X1 [redacted] and a [redacted] Illumination Meter, 25X1
Model 756 with Viscon Filter" ([redacted] 25X1
25X1 [redacted]

* Not measurable, but less than 3000°K.

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GROUP 1
EXCLUDED FROM AUTOMATIC DOWNGRADNG AND DECLASSIFICATION

(5) Practical experience in color duplication and enlarging of thousands of feet of color aerial original films quickly demonstrated that in the color evaluation stage, the following conditions must be satisfied:

(a) The same viewer and ambient lighting conditions must be used for estimating the degree of color corrections and/or final comparison.

(b) Experienced color quality control personnel will individually arrive at a common color balance providing they all use the same viewer. Slight differences (0.05 color corrections) do arise because of individual preference. Sufficient data are not available to use densitometric correlation with known ground target reflectance under all climatic conditions.

(c) A color viewer with variable area, intensity, and color balancing features would be invaluable not only for color evaluation in establishing printer balances, but also for enhancement of target area content by color biasing.

c. Stereo Viewing: Stereo viewing of color and black-and-white pairs (both normal density range when viewed separately) requires the insertion of neutral density over the black-and-white side. This technique subdues the black-and-white image brightness (but not the sharpness) thereby increasing the apparent color saturation of the stereo image. To avoid the handling of neutral density filters, the use of a polarizing system in each optical path would simplify stereo viewing systems. (See Figure 14).

d. Reflection Prints:

(1) The basic requirements for viewing color reflection prints have been outlined in the ASA Standard PH 2.23-1961 referred to previously.

(2) One commercially available equipment item tested and known to meet these requirements is the [redacted] Avlite Standard Viewer Model T-240. The unit is useful for viewing both reflection prints and transparencies. The [redacted] Avlite Standard Viewer Model R-240 also meets this standard but is suitable for reflection prints only.

25X1

25X1

CONCLUSIONS

11. General:

a. Study of the various facets of color reproduction revealed the need for new equipment, modified equipment, new uses for currently available materials, requirements for new products, and new approaches to current problems. Positive approaches to the problems and their successful solution are believed realistic and possible, but not necessarily easy or without extensive effort.

b. Successful color reproduction must be considered as a part of the acquisition planning. The two phases cannot be separated in practical plans or studies.

c. As the study progressed, logistics problems appeared more frequently. Therefore, logistics should have a significant effect upon recommendations.

12. Materials:

a. General Effects of Acquisition System Types on the Choice of Color Reproduction Materials: These effects are related here to the contrast of the color duplicating film, since the speed, resolution and color balance characteristics must be satisfactory before the film can be chosen. The listing below indicates "HIGH" and "LOW" contrast as comparative terms applicable to the available and recommended reproduction materials.

Type Acquisition System is:	Contrast of Duplicating Film for Acquisitions at High Altitude:	Contrast of Duplicating Film for Acquisitions at Low Altitude:
Single-Film (color only)	HIGH (non-stereo) HIGH or LOW (stereo)	LOW
Two-Film (color/black-and-white)	HIGH	LOW
Two-Film (both color)	HIGH (non-stereo) LOW (stereo)	LOW

b. Operational and test experience with color acquisition and reproduction systems has been limited. Guides have been established for further testing to extend this experience and refine the choice of materials for reversal and negative-positive systems. These guides are adequate to cover the production of duplicate transparencies, reflection prints and stereo pairs. Significant improvements are possible in these areas. Operational improvements can be sought along with study of additional material and equipment subjects recommended in this report or new subjects such as camouflage color detection.

c. Equipment limitation is a factor in the choice of materials. Some of the films tested were equipment limited preventing effective full-scale use. For example, some of the films were too slow for printing on current continuous equipment by the additive method.

d. Duplicates with improved color saturation, color brightness and hue were produced by the additive printing technique as compared to

subtractive printing. The additive system should be further exploited for use with all suitable color reproduction materials.

e. The emphasis of investigations on optimum quality of the second generation duplicate has resulted in a clear indication that color enhancement of this copy can be achieved as compared to the camera color original.

13. Equipment:

a. Continuous Contact Printers (Niagara Type)

(1) Continuous contact printers are capable of good quality and consistent repeatability with printing speeds up to 82 feet of film per minute for some films.

(2) These printers have been used successfully for the multi-strand printing of three (3) 70mm records on a single-strand of 9.5-inch film thus permitting an increase in effective processing capacity in terms of 70mm output.

(3) Printer light intensities are not presently adequate for "tri-color" printing of slow speed duplicating films.

(4) More investigation is needed to enable design or modifications for:

(a) Negative-positive film systems.

(b) Within-frame printing to correct for the color imbalances caused by the angle of acquisition, solar altitude and the effects of haze.

b. Step Printers:

(1) Experience has been limited to a modified "Morse" printer. The efficiency of the light source in this printer is low, making excessively prolonged exposures necessary. Printing results showed the effects of reciprocity failure to some degree.

(2) Design requirements and desirable features have been established as noted in the discussion on page 30 (also noted is the fact that step-and-repeat color printers are now being designed).

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MODIFIED HAND STEREOSCOPE FOR COLOR-BLACK AND WHITE PAIRS

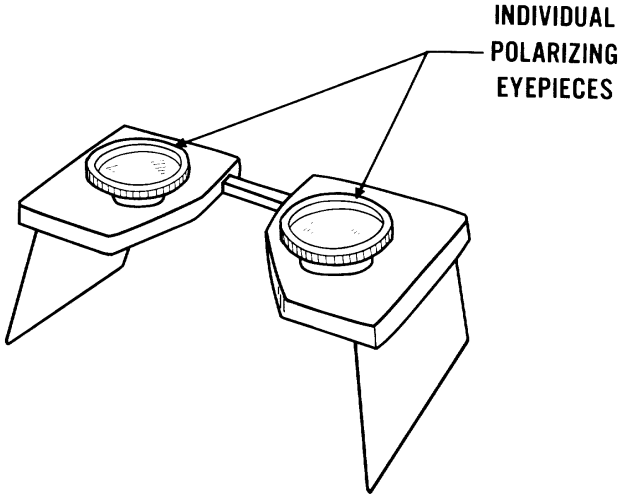

FIGURE 14.

(3) A major design feature is the capability for "tri-color" (additive) printing to optimize color reproduction quality.

c. Color Enlarging Printers:

(1) The best enlargements are those made directly from the original, but this is not a practical approach for simultaneous community requirements.

(2) Negative-positive systems offer a practical approach. This approach would provide an internegative made directly from a color positive original to be supplied along with a color positive copy (also made directly from the original). Further reproductions could then be made from the internegative.

(3) Enlargements (third generation) made from second generation or contact printed positive copies result in losses of image sharpness, color fidelity and tone reproduction.

(4) Step enlarging has been moderately successful with commercially available equipment. The major problems were:

(a) Illumination fall-off.

(b) Off-axis sharpness loss.

(c) Subtractive printing.

(d) Prolonged exposure times.

(5) Efficient high-speed continuous enlarging is desired to gain the maximum benefit from color materials. Equipment of this type is not presently available. Continuous enlarging printers may be characterized by simple basic principles, but also by complex design problems.

(6) The requirements for enlarging printers have been determined as follows:

(a) "Tri-color" narrow band light sources (additive printing).

(b) Sufficient illumination intensity to minimize reciprocity effects resulting from prolonged exposures.

(c) Color-corrected lenses.

(d) Field flatness and uniformity.

(e) Improved image sharpness over the entire field.

(f) Magnification up to 20X in one stage.

(g) Roll heads to accommodate various film and/or paper widths for both the platen and the easel.

(7) Other desirable features are:

(a) Auto focus (step enlarger only).

(b) Automatic scan and "dodging" for each primary light source.

d. Light sources are most important elements in the design of printers intended for color work, and should be considered concurrently with the design effort.

e. 1:1 Optical Printers: Equipment is not commercially available for use with aerial film widths and such equipment is not considered feasible to date.

f. Processors, Continuous Deep Tank:

(1) In-house reversal equipment has produced satisfactory quality machine processing of Ektachrome type materials. Capabilities and limitations are:

(a) Single-strand film widths from 70mm to 9.5-inches.

(b) Pilot to semi-production operation.

(c) Output capacity limited to five feet per minute.

(d) Single-strand 9.5-inch film bearing three separately printed 70mm reproductions can be processed to increase processor output capacity of 70mm duplicates. This requires the added operation of slitting.

(2) A negative-positive processor under testing provides satisfactory processing of transparency and reflection prints, but has an output of only 2.5 feet per minute.

(3) Processors are most effective when designed for specific processes and have built-in systems for the control of temperature and agitation.

(4) Design of full-scale production equipment could be started now for reversal color processing, but negative-positive systems need further investigation. Existing equipment will continue to be useful in a supporting role for testing and limited production.

g. Processors, Roller Transport: Design principles for this type of equipment have proved successful for black-and-white materials. Advantages and disadvantages for use with color are unique in most cases.

(1) Major Advantages:

(a) Efficient use of chemicals.

(b) Adaptability for multi-purpose use by interchanging modules.

(c) Suitability, without modification, for continuous long length or intermittent short length operation.

(2) Major Disadvantages:

(a) The large number of rollers increases the danger of damage to the emulsion of color materials.

(b) Processing time changes are difficult for individual modules. All dwell times are constant for a given machine speed and rack size.

(c) Rapid chemical exhaustion in small capacity tanks may create problems even with a replenishment system in operation.

h. Processors, Drum-Type: Equipment is not commercially available for continuously processing color films.

i. Processors, Small Scale:

(1) Equipment is commercially available.

(2) Acceptable results were achieved for film lengths up to 25 feet in the "Nikor" reel unit.

(3) Precise times and temperatures are critical and difficult to maintain. A recently devised "programmer" was used with success for accurate timing. (See Figure 13).

(4) The eleven equipment-chemical systems tested revealed other basic problems with small-scale operation as follows:

(a) Nonuniformity and streakiness (B-5 system).

(b) Agitation variation for long lengths.

(c) Thin base film loading difficulty ("Nikor" reel).

(5) Best results require that equipment be compatible for sizes and techniques involved.

(6) Small-scale systems are particularly useful in a continuing program of materials and systems evaluation.

j. Processors, Viscous Color Negative:

(1) Equipment of this type may simplify or eliminate control of variations in chemicals, agitation and temperature.

(2) More study is needed.

(3) Pilot testing might be initiated with a modified black-and-white viscous processor.

k. Post Processing Equipment:

(1) Film cleaning with solvents is preferred over the use of tacky rollers which tend to damage color emulsions.

(2) Lubrication methods need further study.

(3) Black-and-white titling equipment can be used successfully with color, but requires titling of all copies separately. Better methods are needed.

(4) Estar Thin Base requires better control devices than available on current equipment for precision slitting.

1. Viewing Equipment:

(1) Limitations of current equipment restrict the reference aim to reproductions of scenes acquired at the nadir, so that the operator is obliged to compensate mentally for color and density changes in oblique photography.

(2) Some requirements for viewing transparencies are:

(a) Color-corrected optics.

(b) Ambient lighting at 3800° ± 200° color temperature and variable intensity to provide incident diffuse light equivalent to 10% to 25% of the transmitted light.

(c) Flat neutral gray walls in the viewing room with 18% to 30% reflectance.

(3) The same or equivalent viewer and conditions must be used to estimate color corrections and make final comparisons.

(4) Experienced quality control operators using the same equipment will arrive at a common color balance within ± 0.05 color correction.

(5) A variable area, intensity and color viewer should be of benefit to quality control and photo interpreter operations.

(6) Color and black-and-white stereo combination viewing can be successfully done with relatively simple equipment. Modifications for improvement are also simple.

RECOMMENDATIONS

14. General: Retain the scope of this study in a continued program, and initiate detailed planning for further study as early as possible in order to make the best use of information generated thus far.

15. Materials:

a. Recommended Color Reproduction Systems (See Table 1): Choice of materials is best represented in the referred table; however, those listed can be recommended for the particular features which place them in the table. A scan of Table 1 should be more meaningful after a reading of (1) through (8) below:

25X1 (1) [redacted] Special Color Film (Estar Thin Base), Type SO-121 is recommended as a reproduction material primarily due to its resolution and where high contrast is desired in the reproduced copy. Color copies on this material are excellent for stereo viewing with black-and-white. It is not recommended for use beyond the second generation, or for duplicating high-contrast originals.

25X1 (2) [redacted] Special Color Duplicating Film, Type SO-271 is a medium contrast product suitable for reproductions of color originals having low density ranges and where resolution is less important than color fidelity. It is useful in making an enlarged record of an original acquired at medium to high altitude. Copies contact printed on this material provide medium color saturation when viewed in stereo with black-and-white. Resolution of contact prints may be acceptable if the original has a large ground scale and resolution is not critical.

25X1 (3) [redacted] Film, Type SO-344 is an excellent product for resolution and low contrast. It is useful for color copies of low altitude acquisitions, where matching the color original is desired. Its use for high altitude copies is limited by low contrast. It may be used to copy a high altitude original where resolution is more important than color enhancement; but such copies are not usable for stereo viewing with black-

TABLE 1

RECOMMENDED COLOR REPRODUCTION SYSTEMS

Acquisition Altitude of the Original	Contact Positive Print Materials			Enlargements - Direct from the Color Original					
	Primary Viewing Use			Reversal Systems		Negative-Positive Systems			
	Direct Viewing	Stereo Viewing		>3X Positive Transparency	Predicted Image Contrast	Negative Materials		Positive Materials	
		Side 1	Side 2			Contact	>3X	Transparency	Reflection
High to very high - above 50,000 feet (See Note 1)	SO-121 SO-344 8442 *	SO-121 8442 * SO-344	B&W ** B&W ** SO-344	SO-121 8442 SO-271 SO-344	High High Medium Low	5270	5270 KEI **	KEP **	EPPP **
Low to Medium - up to 15,000 feet (See Note 2)	SO-344 SO-271	SO-344 SO-271 SO-344 SO-271	B&W ** B&W ** SO-344 SO-271	SO-344 SO-271	High Very high	5270 KEI **	5270 KEI **	KEP **	EPPP **

Note 1: High contrast color original material is assumed for these altitudes. No attempt is made to relate acquisition camera resolution capability to the acquisition film.

Note 2: Medium contrast color original material is assumed for these altitudes because of a higher scene brightness range than for high altitudes. It is further assumed that resolution is less critical at these lower level ground scales.

* Type 8442 may be used when the color original has recorded less than 30 lines per millimeter.

** Abbreviations

B&W: Black-and-White
KEI: [redacted] Internegative Film
KEP: [redacted] Print Film
EPPP: [redacted] Professional Print Paper

25X1

25X1

Numerical Designations

SO-121: [redacted] Special Color Film (Estar Thin Base), Type SO-121
SO-271: Color Duplicating Film, Type SO-271
[redacted]

25X1

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and-white.

25X1 (4) [redacted] Ektachrome Aero Film, Type 8442 is usable where high contrast in a color film is desired and resolution is less important. The material has an extended latitude resulting in better shadow and highlight colors for higher contrast scenes. It may also be considered as a high contrast medium for direct enlarging at greater than 3X.

25X1 (5) [redacted] Color Internegative Film, Type 5270 is the best material tested for selected area enlarging. It has excellent resolution and color fidelity characteristics for this purpose. Further, it may be considered as a medium for contact printing internegatives from the color original.

25X1 (6) [redacted] Ektacolor Internegative Film is excellent for enlarging directly from the original. When contact printed from aerial acquisition originals, this medium cannot retain the resolution normally required. It is useful also in studio type work or for low altitude internegatives where resolution may be less critical.

25X1 (7) [redacted] Ektacolor Print Film is recommended for use with either of the two internegative materials providing the original image has been enlarged. This material has excellent color fidelity but because of resolution limitations should not be used for contact prints from contact printed internegatives. Transparencies made on this material have medium contrast relative to the internegative.

25X1 (8) [redacted] Ektacolor Professional Print Paper is recommended for use where enlarged reflection prints are desired. It should not be used for contact printing a contact printed internegative because of the resulting loss in resolution. Apparent image contrast can be controlled partially by the type of print surface desired.

16. System Improvements:

a. Improve color reversal and negative-positive systems by "tailoring" reproduction processes to specific potentially usable films.

b. Establish specific data for color printing of both transparencies and reflection prints.

c. Examine new materials for applicability. This effort is continuous in nature to assure the best reproduction system choices.

17. Equipment:

a. Continuous Contact Printers:

(1) Improve current printers for narrow band additive printing of the slower speed color duplicating films.

(2) Control gross printing level by neutral density filters and fine adjustment by lamp voltage to minimize color temperature shift in the lamp.

(3) Investigate the use of the modified Niagara or Colorado type printers for color negative-positive systems.

b. Step Printers: Review and test potentially useful equipment as it becomes available.

c. Enlarging Printers:

(1) Design and fabricate a high output continuous enlarging printer for full exploitation of color. This facility would make practical the providing of a continuously enlarged color negative made directly from the original. The degree of enlargement should be 3X or greater.

(2) Improve step enlarging equipment to incorporate narrow band additive printing techniques.

d. Printing, General:

(1) Investigate light sources as part of equipment design.

(2) Study within-frame color and density correction problems for feasibility. Make "breadboard" tests.

e. Processors, Continuous Deep Tank:

(1) Design and construct an efficient production scaled processor capable of 20 - 40 feet per minute output. Include consideration of multi-strand 70mm capability.

(2) Modify existing equipment for higher speed operation, and maintain it for testing and pilot plant back up in support of mission processing.

f. Processors, Roller Transport: Consider this equipment with color reversal systems for tactical or low altitude reconnaissance support, or with negative-positive systems for large scale preparation of print materials.

g. Processors, Small Scale: Keep abreast of the latest developments with such equipment to take advantage of its testing and pilot plant support capabilities.

h. Processors, Viscous Color Negative: Continuous viscous color negative equipment has good use potential and should be investigated early. Initiate feasibility studies.

i. Post Processing Equipment:

(1) Establish requirements for cleaning and lubricating of films.

(2) Devise a method of titling color positive originals which will reproduce the title photographically when copies are printed.

j. Viewing Equipment:

(1) Initiate an investigation to determine the problems in using the current ASA viewing recommendations and the degree of variance which might be desirable due to special problems. This primarily pertains to transparencies but may include reflection prints.

(2) Determine the most suitable commercial equipment for measuring color temperatures and intensities.

(3) Design and build a variable area, intensity, and color balance viewer to assist in the exploitation and evaluation of color transparencies. It should also be capable of handling long lengths of film 70mm to 9.5-inches wide and have a viewing area at least 30-inches long.

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APPENDIX

18. Characteristic Curves and Data for Color Duplicating Materials: A graph of the characteristic color curves is given -- along with some of the basic capability and handling data -- for each of the following materials:

25X1 a. [redacted] Special Color Film (Estar Thin Base) Type SO-121.

25X1 b. [redacted] Aero Film, Type 8442.

c. Special Color Duplicating Film, Type SO-271.

25X1 d. [redacted] Film, Type SO-344.

25X1 e. [redacted] Color Internegative Film.

25X1 f. [redacted] X (Currently applicable to [redacted] Internegative Film). 25X1

25X1 g. [redacted] Print Film.

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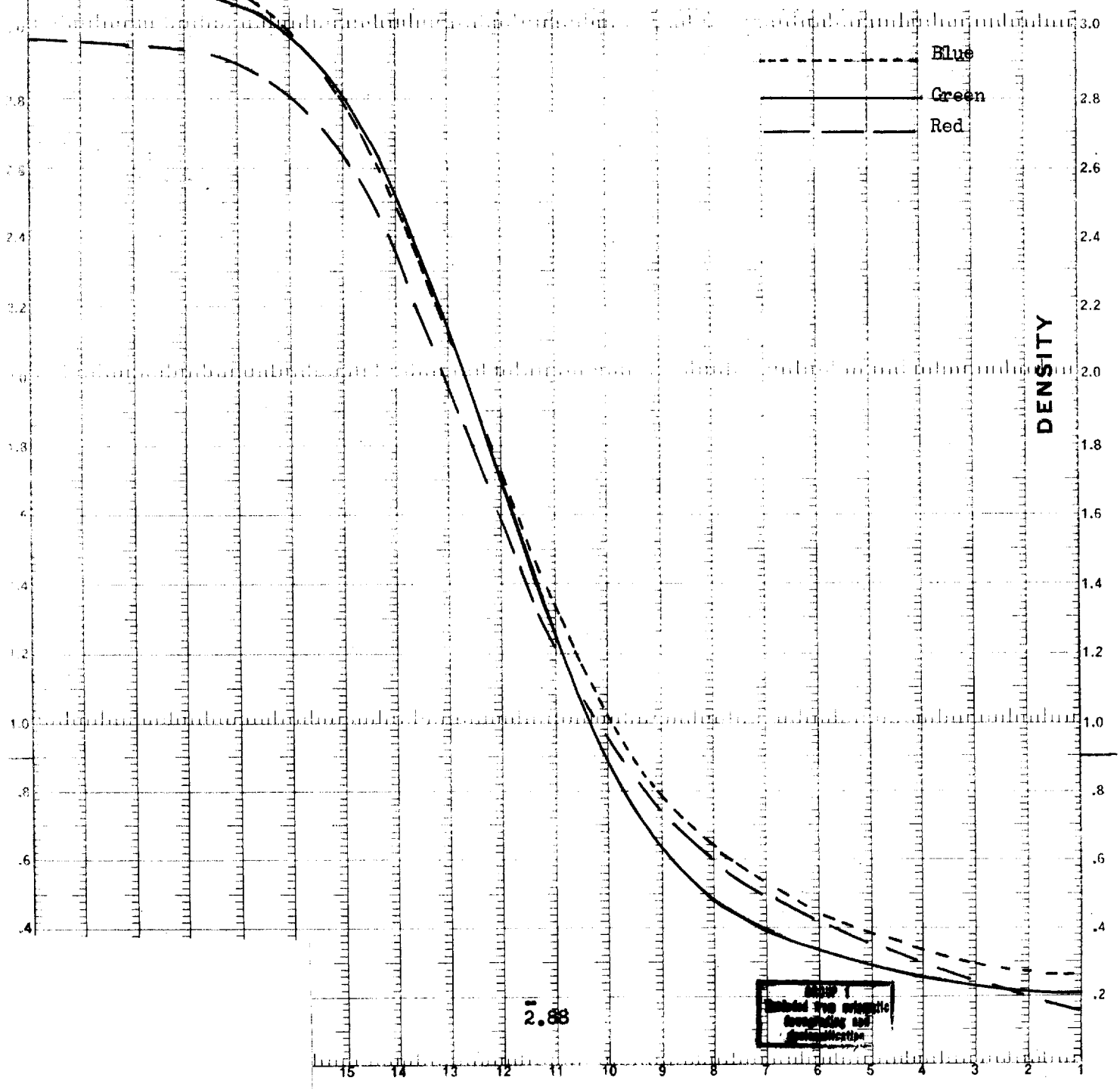
GROUP 1
EXCLUDED FROM AUTOMATIC DOWNGRADNG AND DECLASSIFICATION

25X1

Film: [redacted] SPECIAL COLOR FILM (ESTAR THIN BASE) Type SO-121
Use: High altitude reconnaissance

Overall Thickness: 3.5 mils
Resolving Power TOC 10:1 125 lines/mm
TOC 1.6:1 75 lines/mm
Process: Modified ME-4
Safelight: Total darkness required
Exposure Index: 13
Illuminant: Daylight + Wratten 2E
Log E_{11}: 2.88



25X1

Film: [redacted] AERO FILM, Type 8442
Use: High altitude reconnaissance

Overall Thickness: 6.1 mils
Resolving Power: TOC 10:1 100 lines/mm
TOC 1.6:1 32 lines/mm
Process: Modified ME-4
Safelight: Total darkness required
Exposre Index: 25
Illuminant: Daylight + Wratten 2B
Log E_{11}: 2.67

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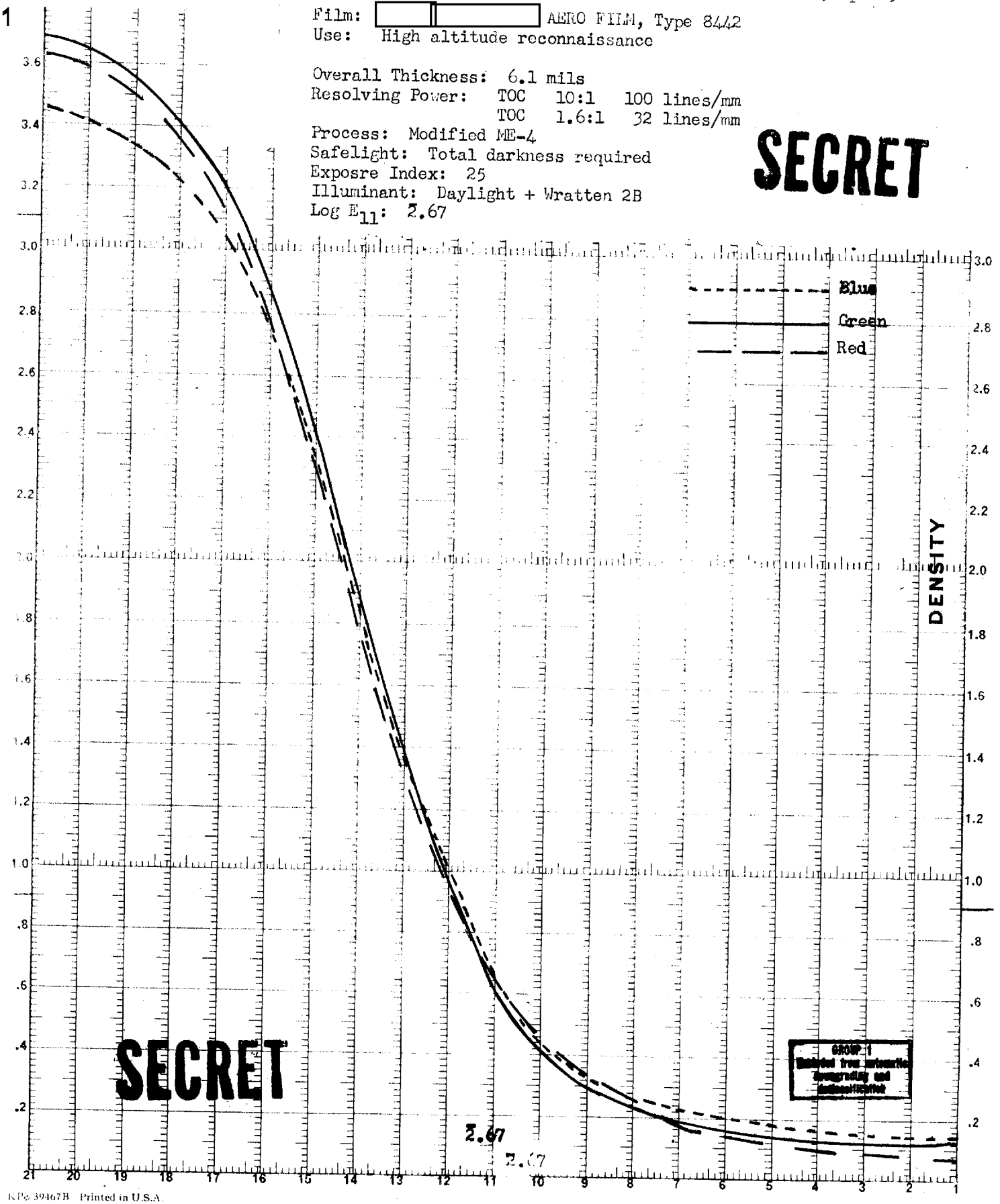

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KPo 39467B Printed in U.S.A.

25X1

Film: [redacted] SPECIAL COLOR DUPLICATING FILM, Type SO-271
Use: Medium contrast color reversal film for duplicating.

Overall Thickness: 6.3 mils
Resolving Power: TOC 10:1 71 lines/mm
TOC 1.6:1 32 lines/mm
Process: Modified ME-4
Safelight: Total darkness required
Exposre Index:
Illuminant: 3000°K + .30G +.30Y @ 0.2 sec.
Log E_{11}: 0.86

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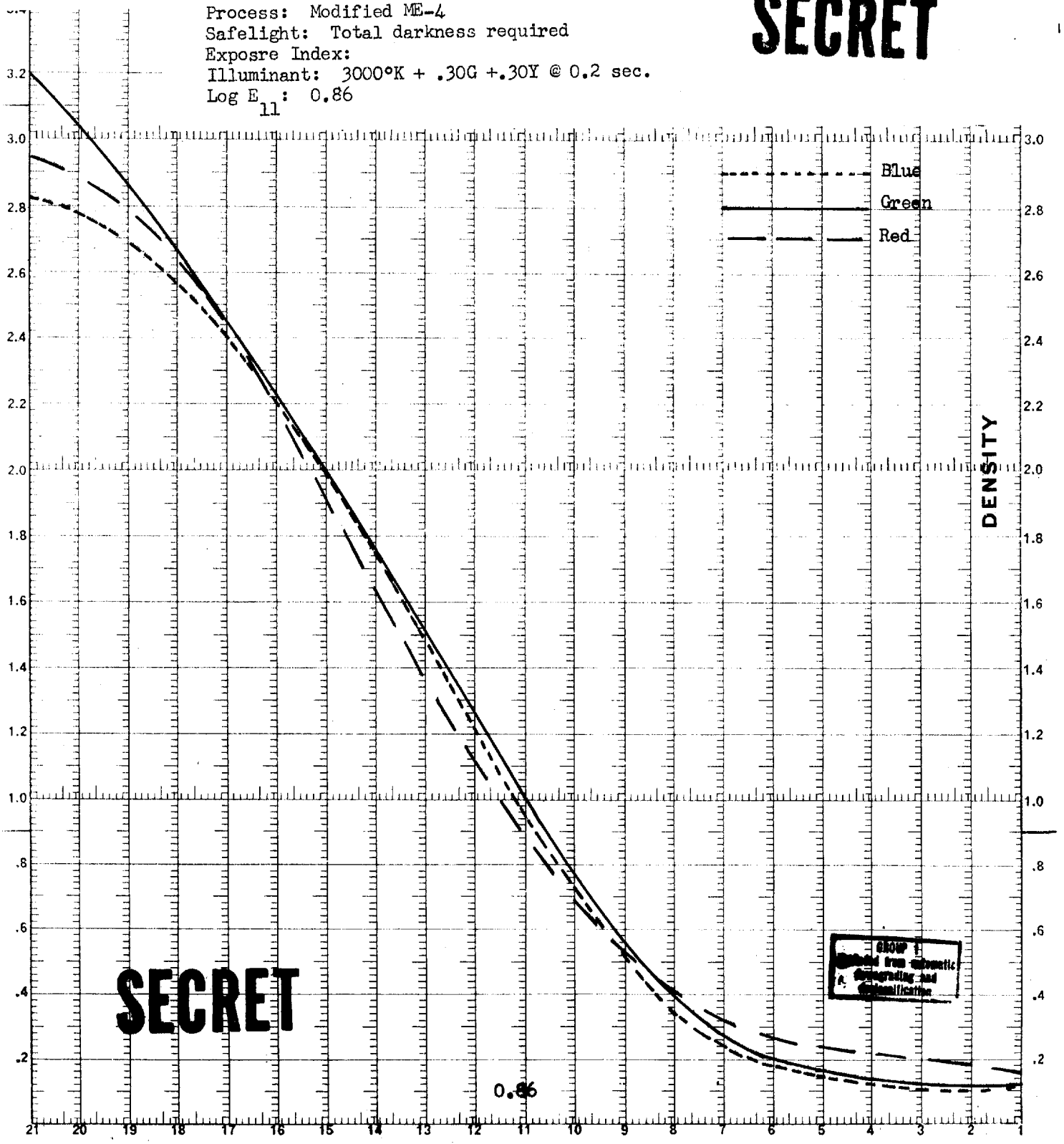

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KP¢ 39467B Printed in U.S.A.

25X1

Film: [redacted] FILM, Type SO-344
Use: Low contrast color reversal film for duplicating

Overall Thickness: 5.9 mils
Resolving Power: TOC 10:1 90 lines/mm
TOC 1.6:1 35 lines/mm
Process: ECO-2
Safelight: Total darkness required
Exposure Index: 5
Illuminant: 3000°K @ 0.02 seconds
Log E_{11}: 1.27

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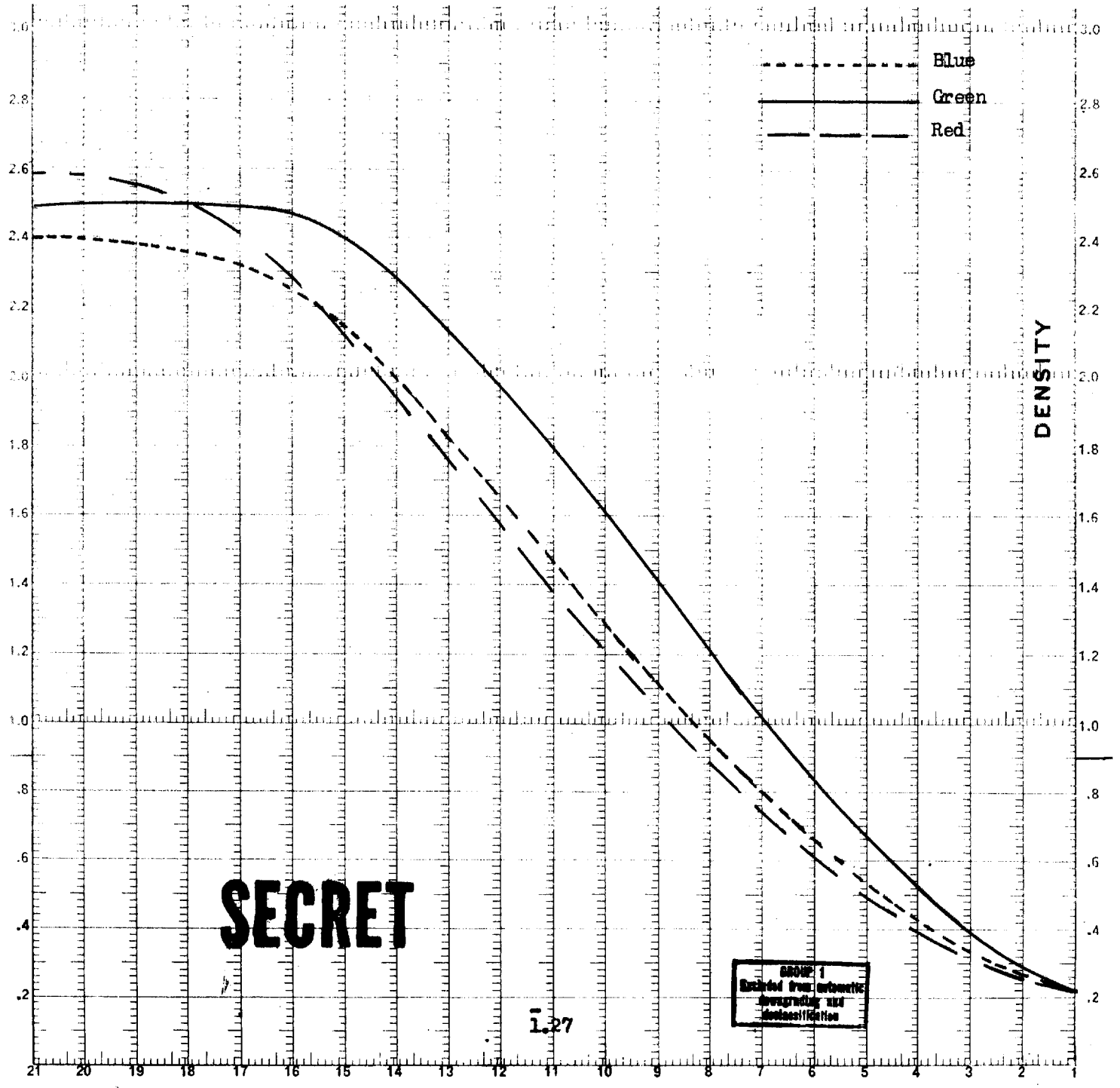

GPO 39467B Printed in U.S.A.

25X1

Film: [redacted] COLOR INTERNEGATIVE FILM
Use: Internegatives from color reversal originals

Overall Thickness: 6.2 mils
Resolving Power: TOC 10:1 190 lines/mm
TOC 1.6:1 58 lines/mm

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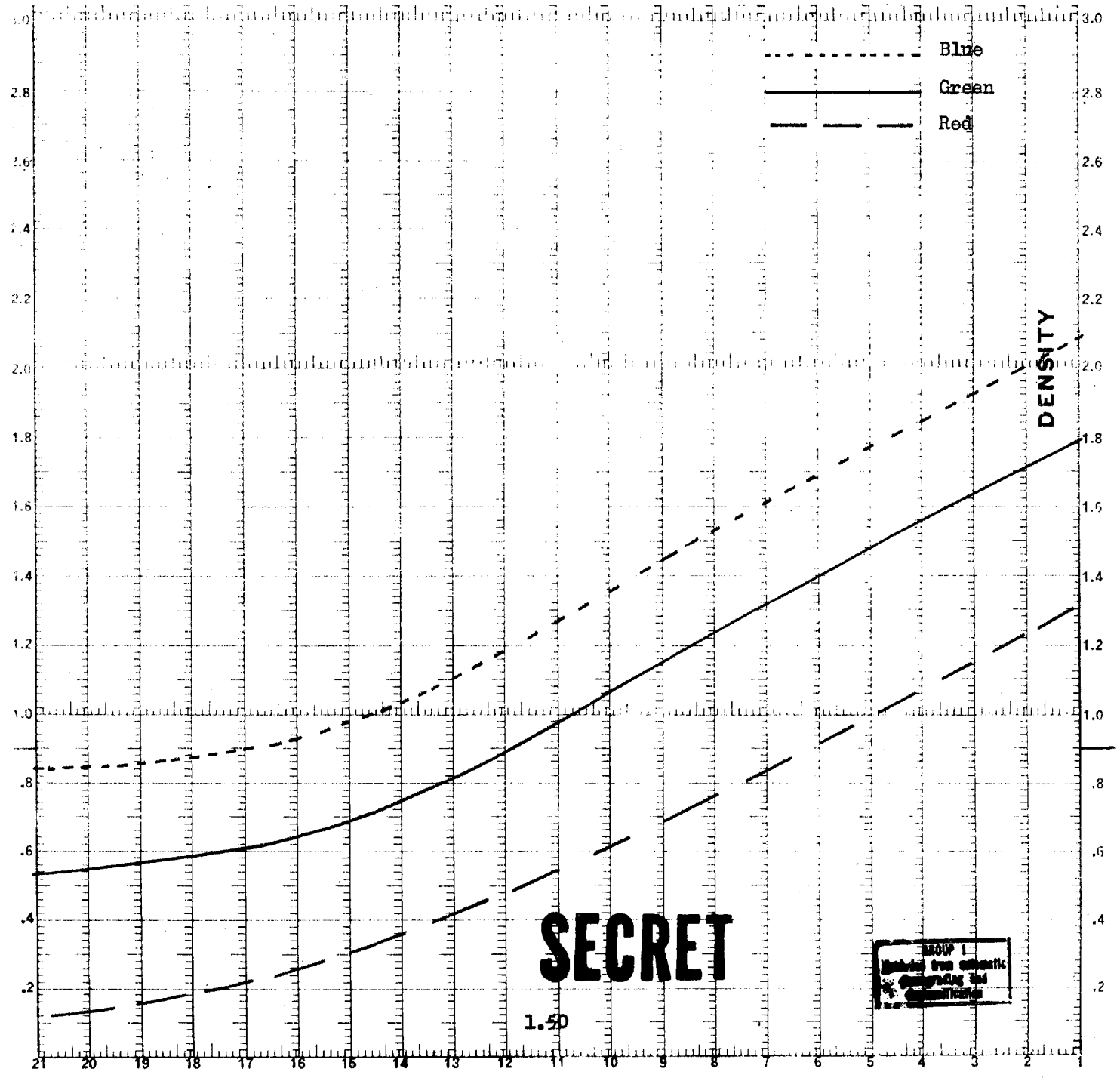
25X1

Process: [redacted] Color Print
Safelight: Total darkness required
Illuminant: 2850°K + Wratten 2B @ 0.04 seconds
Log E_{11}: 1.50



KPφ 39467B Printed in U.S.A.

25X1 Film: [redacted] X (Currently applicable to [redacted] Ektacolor Internegative Film) 25X1
Use: Internegative from color reversal positive

Overall Thickness: 6.1 mils
Resolving Power: TOC 10:1 48 lines/mm
TOC 1.6:1 22 lines/mm

Process: C-22
Safelight: Total darkness required
Illuminant: Daylight @ 0.01 sec.
Log E_{11}: 2.70

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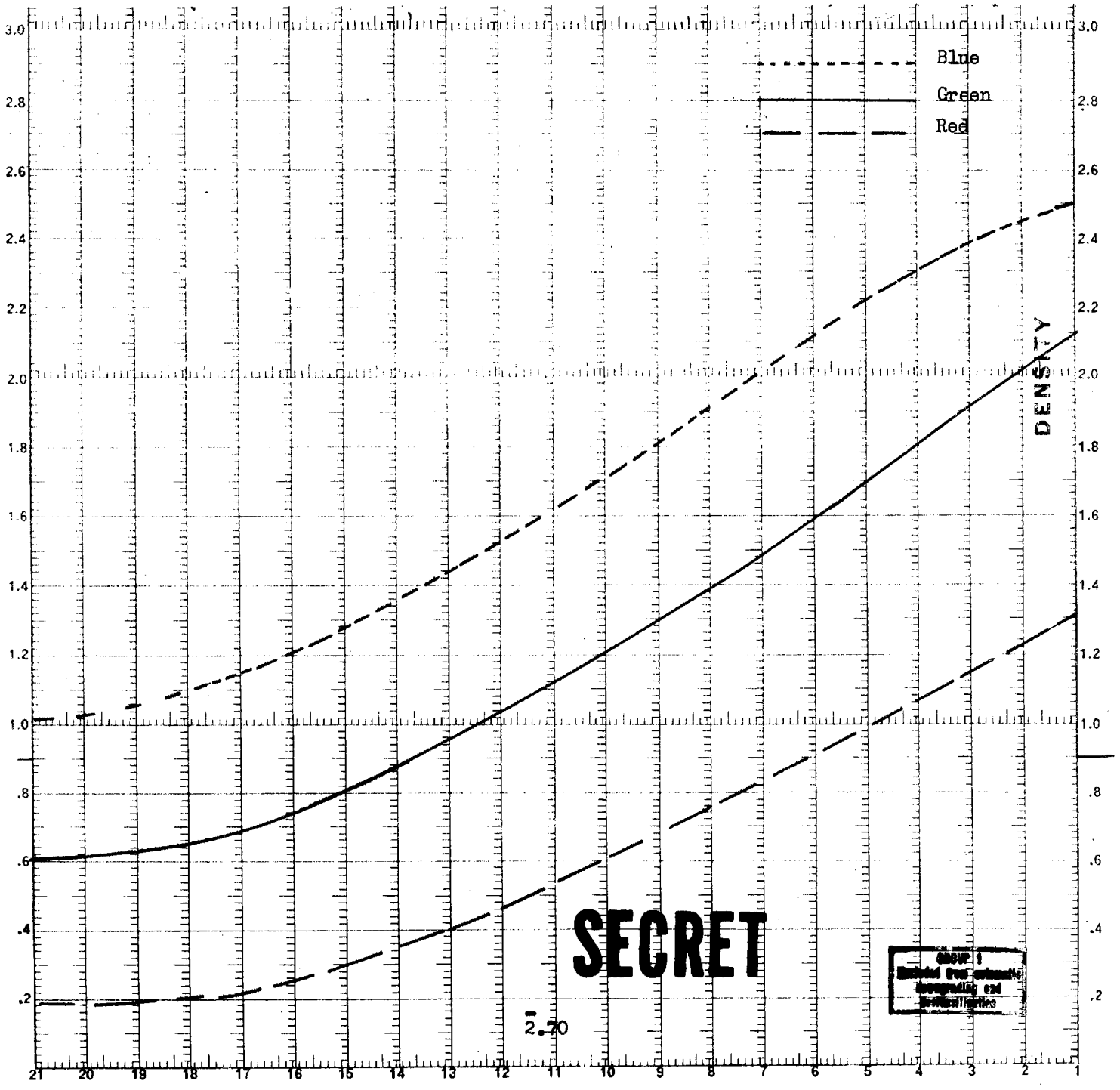

KP6 39467B Printed in U.S.A.

25X1

Film: [redacted] PRINT FILM

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Use: Positive transparancies from color negatives.

Overall Thickness: 9.3 mils
Resolving Power TOC 10:1 56 lines/mm
TOC 1.6:1 28 lines/mm

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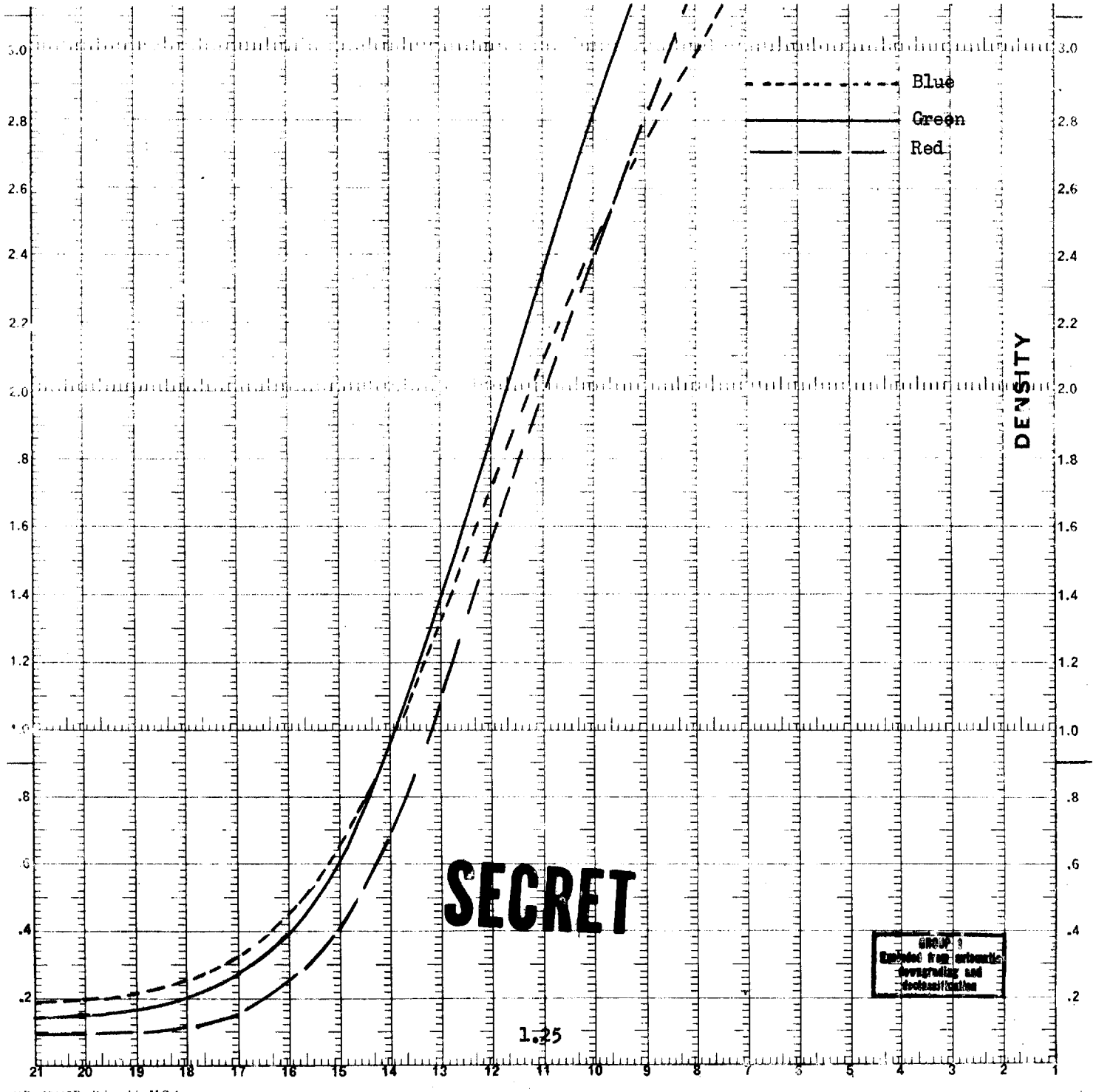
Process: C-22
Safelight: Total darkness required
Exposure Index:
Illuminant: 500 watts, 3000°K with Wratten 2B
Log E_{11}: 1.25



KPφ 39467B Printed in U.S.A.